TEXT FLY WITHIN THE BOOK ONLY

THE CLIMATES OF THE CONTINENTS

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PREFACE

THE book has been enlarged and entirely reset for this edition. Many sections have been rewritten to bring the treatment up to date. Nearly all the climatic means have been revised, and data for many new stations added, useful material having become available in recent years as a result of the demands of air-navigation in peace and war. Several new tables are included of wind-directions, diurnal temperatures, sunshine, fog, and other elements, to provide a broader foundation for the detail which the practical worker on any area requires.

Primary sources should naturally be the basis of this work; data have been obtained both from official publications, now numerous, most of which originated in, or as a result of, the recent war, and by inquiry and search at meteorological offices, in particular the British, to the staff of which I am greatly indebted for ungrudging help. Secondary sources have been intentionally left aside as much as possible with a few exceptions, notably the indispensable *Handbuch der Klimatologie* of J. Hann among the older authorities, and of moderns the work with the same title edited by W. Köppen and R. Geiger. Personal experience in the course of a certain amount of travel on land and oceans, during residence in four continents, and work in five meteorological services in very diverse regions of the globe, have provided some of the background that is essential for any study of distribution.

An attempt, always hazardous, has been made to choose for more detailed description regions of significance in the world's present turmoil or likely to be prominent in the future.

It is again a pleasure to make the fullest acknowledgement of the use made of existing sources of information, primary and secondary. The great increase in their number is an indication of the growth of climatological studies; for the first edition of this book the difficulty was to find any precise information about many parts of the earth, but now the problem

is rather to select judiciously and compress into the available space.

My sincere gratitude is expressed to friends and other authorities, including many in the meteorological offices, for their ready and valuable help.

W. G. K.

Oxford, 1950

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PART I

INTRODUCTORY

CHAPTER I

CLIMATIC DATA

THE most important of the elements which combine to form climate are temperature and rainfall. These have been more carefully and frequently observed than others such as sunshine, cloudiness, and humidity, which are subsidiary though by no means negligible, and it seems well to make some general remarks here about them as they will be so often mentioned in the following pages.

TEMPERATURE

The air temperature at any place is constantly changing, and it is impossible to give a complete statement of such a varying element. In climatic descriptions it is usual to state the mean temperature, and desirable to indicate in some way how far the temperature may be expected to vary from day to day. 'Mean temperature' is an abstraction, and if it is to be of significance the extremes of the individual figures from which it is derived must not be very far apart. For most of the world the mean for the year is the least satisfactory statement of temperature; Peking (Peiping) and the Scilly Islands have almost the same annual mean, but the monthly means range from 80° to 25° at Peking, from 61° to 43° in the Scilly Islands. In low latitudes, it is true, the annual mean is more useful since the temperature varies less from month to month, but it should be supplemented by the monthly means. Means for a shorter period than a month would be still more valuable, but they entail burdensome statistics.

The mean temperature for a day is usually taken to be the mean of the maximum and minimum recorded in the shade under certain recognized conditions to ensure uniformity; but some of the means quoted are the means of the 24 hourly readings, others are obtained by a combination of the readings at various hours, according to the observations available; all

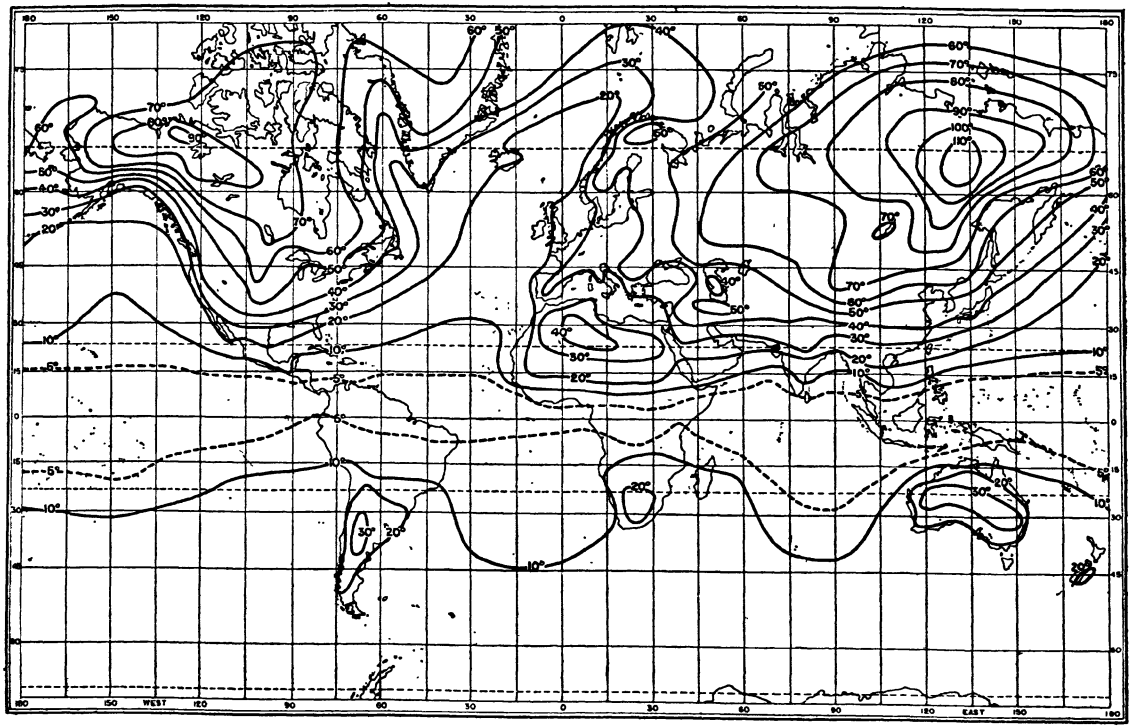


FIG. 1. Mean annual range of temperature. (By permission from Haurwitz and Austin: *Climatology*. McGraw-Hill Publishing Company, London and New York.)

the combinations do not give exactly comparable results. The mean for any month is the mean of the daily means, and the mean for a year the mean of the twelve monthly means. True means are obtained arithmetically from the data for the day, month, or year, for a long period, if possible 35 years. The difference between the means of the warmest and coldest months is the 'annual range', a most important element (Fig. 1).

At Peking the mean annual range is seen from the figures given above to be 55°, in the Scilly Islands 18°; in the neighbourhood of the Panama Canal it is only 1°. The 'mean diurnal range' is the mean difference between the highest and lowest temperatures for each day in the period, usually a month, for a series of years, and it also is a useful figure. For example, London has a mean diurnal range of 20° in July, the mean daily maximum for that month being 74°, the mean daily minimum 54°; the Scilly Islands enjoy a more equable climate, having a mean diurnal range in July of only 9°. The limits within which the mean diurnal range varies over the earth are not so wide as those for the annual range. Both the diurnal and the annual range depend largely on the position of the station, on or near the sea or inland, and on the cloudiness and humidity of the atmosphere, the highest range being in the middle of a desert far from sea-influence. The annual range is controlled very much by latitude also, on which the seasonal change of insolation depends.

It is to be noted that the diurnal range is considerably larger than the annual in many regions, especially near the equator. Thus at Bolobo (Belgian Congo) the mean diurnal range is 16°, the mean annual range only 2°. It may at first seem surprising that the range from day to night should exceed that for the year, which includes 365 days and nights, but no inconsistency is involved, since the annual range is computed from the mean monthly temperatures, in which the daily extremes are combined and neutralize each other.

All the world over the mean annual temperature decreases with increase of altitude at approximately the same rate, about 1° for 330 feet of elevation; Ben Nevis, altitude 4,406 feet, is 15° cooler than Fort William near sea-level at its foot.

Hence for some purposes of comparison it is convenient to 'correct' the actual temperature to its sea-level value by adding 1° for every 330 feet of elevation. In drawing isotherms these corrected temperatures are used, and where isotherms are referred to in this book they are the usual sea-level isotherms. But with this exception temperatures mentioned are observed temperatures not corrected to sea-level, unless the contrary is stated.

A glance at a map of isotherms shows that temperature varies greatly along any parallel of latitude. The mean for the parallel may be obtained by taking the mean of a large number of points spaced evenly along it. The difference between this mean and the temperature at any place on the parallel is the 'anomaly of temperature' for that place, a positive anomaly if it is above the mean, a negative anomaly if below. 'Isanomalous lines' for any month or for the year are lines drawn through places with the same anomaly. The largest anomaly on the earth is over the north-east of the Atlantic Ocean in January, where a large area has a positive anomaly of more than 20°; the British Isles belong to this favoured region (Fig. 96, p. 308). Anomalies are calculated from temperatures reduced to sea-level. They assist us in analysing the complex influences to which the temperature of any place is due by eliminating the effect of latitude; altitude has already been allowed for, and thus they give a simpler picture, showing chiefly the influence of land and sea, ocean currents, and prevailing winds.

In tables of temperatures it is useful to indicate the highest and lowest that normally occur in each month, or, to use the technical terms, the mean maximum and mean minimum for each month; and also the mean daily maximum and the mean daily minimum for each month, these being the means of the 30 daily maxima and the 30 daily minima recorded in the month for a series of years. They can only occasionally be given in this book owing to limitation of space. The extremes that have ever been recorded, the 'absolute maximum' and 'absolute minimum', are also interesting and useful, provided that the records are of sufficient duration. Short records are even less valuable in this connexion than for establishing

means. The longer the period of observation the higher the absolute maximum and the lower the absolute minimum may be expected to prove. Records of less than 35 years, especially for periods of less than a year, are not of great value in any except very uniform climates, but in 35 years samples of the greatest heat and cold to which a place is liable will probably have been experienced. Unfortunately, in lieu of better, some data are given in the following pages which depend on much shorter records; the length of the record is not stated, but they are believed to be the best available.

Precipitation

A statement of the precipitation for the whole year is inadequate. It must be supplemented at least by some indication of the seasonal distribution, and the mean rainfall for each month ought to be given. The significance of the seasonal distribution is well known to the botanist and the zoologist, for it is a matter of fundamental importance to the plant world whether the rain falls in the warm or the cold season. Hence frequent reference will be made to this, since it is not only of interest to the meteorologist but an important factor in the life of plants and therefore of animals and men.

The seasonal distribution or 'régime' is independent of the total amount. Two stations may have twice as much rain in summer as in winter, or in other words they may have the same régime, but the annual total at one may be many times than at the other. Or again, they may have the same annual mean, but the régimes may be different, one station having most of its rain in summer, the other, perhaps, having similar amounts in all seasons. In order to compare more conveniently the distribution over the year at stations with different totals, we may express the rainfall for each month or for each season as a percentage of the total for the year with allowance for the different lengths of the months. The main régimes are:

(i) Equatorial; two seasons of heaviest rain in the course of the year, at or about the time of the overhead sun; intervening months much less rainy but no quite dry season. It occurs only within a few degrees of latitude on each side of the equator, e.g. at Yaundé, Cameroons, but not everywhere in that belt.

(ii) Tropical, between (i) and the neighbourhood of the tropics of Cancer and Capricorn; most rain in the hottest months when the sun is highest; winter a pronounced dry season. We may subdivide into:

(*a*) Inner tropical with two maxima of monthly rainfall, found in some regions between the equatorial zone and the neighbourhood of lat. 10° N. and S.; it approximates to the equatorial régime, but the two maxima following the overhead sun are closer, and winter is a long dry season, e.g. Juba, Sudan.

(*b*) Outer tropical with a single maximum, poleward of (*a*); the two maxima of (*a*) coalesce, and the dry season is longer, e.g. Khartoum.

(iii) Monsoonal, with a marked maximum in summer and a long dry season, much like ii (*b*); occurs both inside and outside the tropics, especially in the east of continents, e.g. Peking.

(iv) Mediterranean; most rain in the winter half-year, with either a single maximum in midwinter or two maxima, in autumn and spring; summer is almost, or quite, rainless, e.g. Athens.

(v) Continental interior, in temperate latitudes, with most rain in summer (late spring and early summer in the steppes); winters much less rainy but not rainless; the periodicity is not so marked as in the monsoonal and Mediterranean types.

(vi) West coastal, in continents in temperate latitudes with abundant rain in all seasons, most in autumn or winter. Mountains modify the régimes as well as increase the amount.

The type of the precipitation is an important element. Rain may be of the thunderstorm type, in heavy showers during the hot part of the day; or cyclonic (frontal), falling irrespective of time of day, and less heavy but often lasting longer than thunderstorm rain; most of the rain of the British Isles is cyclonic. Or again the precipitation may be drizzle, or even dew. Snow is included in precipitation unless specially excepted, 10 inches of snow being on the average equivalent to about an inch of rain. It is useful to know the average number of rain-days, that is days with appreciable precipitation, at least 0·01 inch or 0·1 mm. or other amounts according to the practice of the meteorological service.

WIND

Some tables of frequencies of wind-directions are included. Such tables indicate only approximately the general winds of the district, one reason being that they refer to land stations, where local influences may introduce serious modifications, especially near the sea or large lakes with their land-breezes by night, sea-breezes by day; in some tables means for both early morning and afternoon are given, and the local effect is obvious. The winds at one or two thousand feet above the surface are more representative, but they hardly belong to the surface in the climatological sense.

The amount of cloud is estimated by eye in tenths of the sky covered (according to the scale in use till the end of 1948). The direction and the velocity of the wind also are estimated by eye at most stations, but instrumental records are becoming more common.

In this account most of the records given are means. But the abnormal weather conditions are very important, for the possibility of a long or severe frost, or of a prolonged drought in a region which is usually adequately watered, is the final consideration which may override for the practical affairs of life the mean conditions.

Innumerable local differences of climate depend on such topographical features as slope and exposure, mountain-shadow or shelter, basin or summit, the nature of the soil and its plant cover if any; though these are of minor importance in many regions they may be dominant, for example, for plant-life. This work aims at indicating the main features of the climates described, but in only a few places attempts to refer to the local modifications.

MEAN VALUES

The assumption made above that climatic means computed for series of about 35 years are correct is justifiable for our purpose. But climate is not constant, and the running averages for even 35 years (at stations with the necessary long series of reliable observations) differ, in many cases appreciably;

means for shorter periods are still more variable. Hence no mean, however long the period on which it is based, has absolute validity except for that actual period.

Unfortunately few stations provide long series of strictly comparable observations owing to changes in the instruments used and their position, and in the hours of observing. Many stations have been shifted to new sites at different altitudes, still retaining their old names; this has happened in recent decades with the establishment of aerodromes which take their own observations, the older stations, perhaps some miles distant, being abandoned as redundant. It has been considered advisable to choose series of records that are recent enough to represent the climate of today, but are yet reasonably long; in some few cases the series is necessarily derived from stations at different altitudes in the same neighbourhood which functioned successively, so that no precise accuracy is possible, but nevertheless the means are useful.

Units used in this book. Most temperatures quoted are expressed to the nearest degree Fahrenheit, precipitation to 0·1 inch, and atmospheric pressure to 0·1 millibar; greater refinement would suggest an accuracy which is not attained owing to the differences in the types of instruments used at meteorological stations and their exposure, and in the skill and care of observers. The hours of the observations are not always stated in official records, an unfortunate omission. The 24-hour reckoning of time is used in view of its convenience, e.g. 6.0 a.m. is expressed 0600, 5.15 p.m. 1715. Hours are local standard time unless stated otherwise.

CHAPTER II

PRESSURE AND WIND SYSTEMS

It is not intended to give an introductory account of the distribution of the climatic elements over the globe as a whole as that may be found elsewhere, and our main object is rather to describe the climates of individual countries. But it is useful to sketch the main features of the distribution of atmospheric pressure and the prevailing winds. Generally speaking, pressure is not in itself an element of climate, for its fluctuations, even

where they are greatest, are not perceptible except with the help of delicate instruments. It is only where the pressure is reduced to two-thirds or less of the normal at sea-level that it becomes an element of climate, as for instance on high mountains where a direct physiological effect is produced, the rarefaction of the air causing mountain-sickness. But indirectly pressure, as controlling the wind-systems, may be said to be

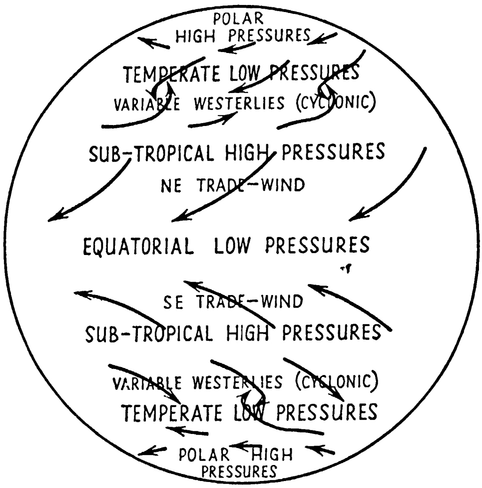


Fig. 2. Planetary circulation of the atmosphere.

a fundamental element everywhere, for climate probably depends more on the prevailing winds and their air-masses than on any other single factor.

The distribution of atmospheric pressure on the globe results primarily from the decrease in temperature from the equator to the poles, and the effect of the rotation of the earth in deflecting the consequent air movements; but the general scheme is greatly modified by the arrangement of continents and oceans, the different thermal behaviour of which imposes large irregularities on the 'planetary' distribution of pressure. These are least in spring and autumn, when the temperature differences over land and water in middle and high latitudes are least; Fig. 2 shows in diagrammatic form the mean pressure-systems and winds in those seasons, but it must be noted that the 'belts' of high and low pressure, and the

wind-systems shown are not permanent or uniform entities, but represent only mean conditions, of varying regularity. The equatorial belt varies least, but small changes of pressure, which may have large effects on winds and weather, are always going on. The sub-tropics have a pronounced tendency to high pressures, but the zone concerned, roughly between 20° and 40° from the equator, never has a regular belt of high pressure, but is rather the scene of large detached anticyclones, most of them moving eastward; over the east of the oceans, between the sub-tropics and the equatorial low pressures, however, the pressure-gradient is remarkably constant, and gives rise to the trade-winds, the most constant winds on the globe. In the temperate low-pressure belts the oscillations are still larger; the mean pressure decreases from the sub-tropics to about 60° N. and S., but the daily charts show a procession of pressure-systems, most of them low-pressure, but some high, of varying shape, size, and intensity, travelling generally eastward at varying speeds and giving the notably changeable winds and weather.

The pressure-belts swing through several degrees of latitude, north in the northern summer, south in the southern summer, but a larger modification is caused by the different temperatures of land and sea in the higher latitudes, especially in the north hemisphere; a result is that in many regions the winds change seasonally.

Fig. 3, based on Hettner (*Die Klimate der Erde*), shows, again in diagrammatic form, the distribution actually found. The continents are represented by a triangle with its base in the north and its apex in the south hemisphere to suggest the main land-masses of the earth. In the first diagram it is summer in the north hemisphere and the pressure-belts have swung north. The land in the summer hemisphere has heated rapidly and low pressures spread and deepen over it. The low-pressure system so formed is an extension of the equatorial low pressures, and breaks the continuity of the sub-tropical high pressures. The air thrown off from the heated continents finds a place partly in the winter hemisphere and partly over the relatively cool oceans of the summer hemisphere. The sub-tropical high pressures of the summer hemisphere are represented by detached anticyclones over the oceans, where

pressure is higher in summer than in winter, and the low pressures of temperate latitudes coalesce with the continental low pressures. In the south hemisphere the land is cool, but its area is small and it makes no great disturbance of the planetary belts.

The planetary winds are modified, in places almost beyond recognition, by these modifications in the pressure. The SE.

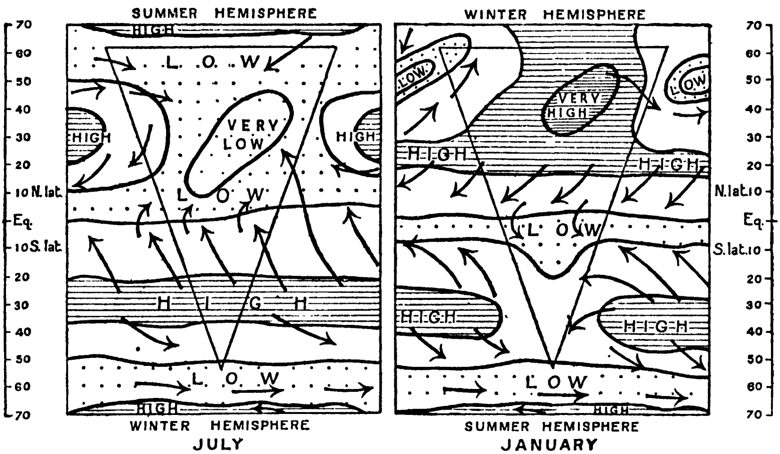


FIG. 3. Diagrammatic surface pressure and winds on a continent and surrounding oceans.

trades are drawn across the equator into the north hemisphere, and coming under the influence of rotational deflexion to the right appear as SW. winds, generally light in force, which will be referred to in later chapters as 'deflected trades'; on the east of the continent they penetrate far into the north hemisphere as the summer monsoon. Thus in the summer hemisphere the trades persist only in the east and middle of the oceans in their appropriate latitudes on the east and south of the sub-tropical anticyclones, blowing from the north on the east of the centre of high pressure, from the north-east on the south-east, and from the east on the south. Over the ocean north of the sub-tropical anticyclones the wind is westerly in summer as in winter, but lighter in force. It is attracted towards the continent and becomes in places NW. On the north coast the wind is north-easterly.

In January (second diagram of Fig. 3) the land in the north hemisphere is much colder than the sea, and the sub-tropical high pressures are intensified over it. But the outstanding feature is the vast 'cold' anticyclone, an extension from the high pressures of the Arctic. The oceans have relatively low pressures, but the sub-tropical high-pressure belts can be clearly seen, though in a much weaker form than in July. The low pressures

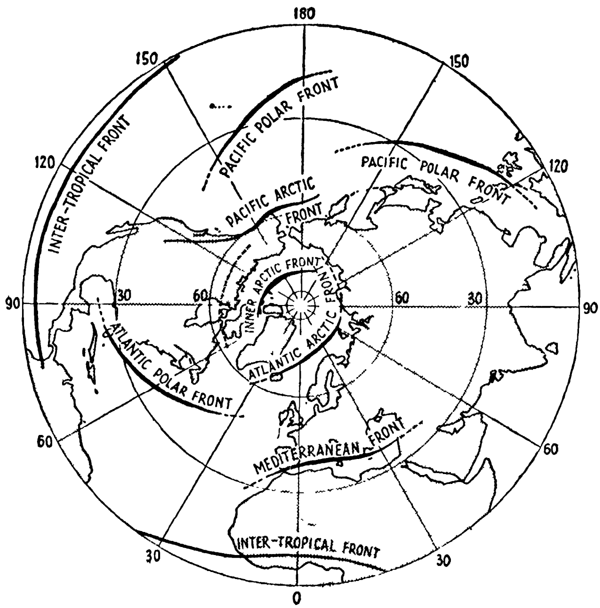


FIG. 4. Frontal belts, winter. (By permission from Petterssen, S., *Introduction to Meteorology*. McGraw-Hill Publishing Company, London and New York.)

of temperate latitudes are deepened on the oceans to form the semi-permanent depressions (the Icelandic and Aleutian systems). From the continental anticyclone cold, dry, polar air streams out on the east to, and beyond, the equator, blowing first from NW., then N., NE., and in the south hemisphere NW.; origin and character distinguish it from the true trade-wind, but with this reservation the trade girdles the globe in the winter hemisphere. The stormy westerlies sweep the northern oceans; their direction is variable from day to day, under the control of the depressions which travel generally from west to east; the prevailing air-movement is from

west and south-west on the equatorial side of the most frequented cyclone tracks. The north of the continent has westerly winds, making the westerlies continuous round the globe, but thrust poleward by the continental anticyclone, so that temperate latitudes have SW. winds on the west of the continent, W. on the north, and NW. on the east, the interior being a region of comparatively calm air.

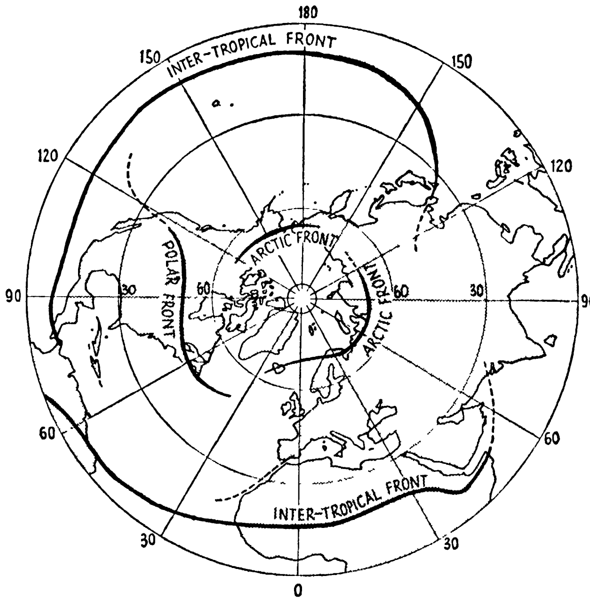


FIG. 5. Frontal belts, summer. (By permission from Petterssen, S., *Introduction to Meteorology*. McGraw-Hill Publishing Company, London and New York.)

The land in the south hemisphere is warmer than the sea in January and the equatorial low pressures spread south, not so much, however, as into the north hemisphere in July, since the land is smaller. The NE. trade is drawn south over the equator and becomes a NW. wind. The SE. trade is deflected towards the heated land to arrive as an E. wind, in places NE., so that the trade-winds are interrupted as in the north hemisphere in July, though to a less extent.

Air-masses and Fronts. Air-movements have been described above in terms of the winds. But 'wind' indicates only the direction and speed of movement of the air; for

many purposes it is more useful to consider the air itself which is in movement, as an entity with its own properties of temperature, humidity, and lapse-rate.

The lower atmosphere is a mosaic of bodies of air, 10,000 feet or more in depth and ranging in area up to millions of square miles. Some are stationary, others in movement. They all possess properties acquired either by 'conditioning' from the surface on which they originally rested for days or weeks, or by subsidence from the upper air. At their sources their properties are those normal to the region; but sooner or later, under a changing pressure-gradient, they move away, retaining those properties modified by the surfaces travelled over but still very perceptible after thousands of miles.

Some regions are normally under the same air-mass throughout a season with little variation, and have fairly uniform weather of the type appropriate to it; the climate of China in winter is fundamentally that of the cold, dry, and dusty 'continental polar' air-mass from the interior of Asia, which sweeps over it with little intermission. In lower latitudes 'maritime tropical' air-masses, originating by subsidence in the sub-tropical high pressures on the oceans, cover vast areas; they are carried along in the trade-winds, and the constancy of the weather in the trades is the result of the uniformity of the air-masses. Other regions, notably in the westerlies, have very variable weathers under a sequence of air-masses of different origin and character; in winter northwest Europe may be under 'maritime polar' air, conditioned in Greenland or the Arctic and modified by its ocean passage, or mild 'maritime tropical' air from the Azores anticyclone, or warm 'continental tropical' air from the Sahara, or, at the other extreme, 'continental polar' air from Russia, very cold and dry, and responsible for the most severe winters when it is persistent.

The nature of the air-masses is evidently more significant than the mere wind-directions; a useful indication of it may be obtained from a study of the track and fetch of the winds, their source-regions, and the surfaces over which they have travelled.

Air-masses are separated by remarkably sharp discontinuities, often forming active 'fronts' in which vertical movements

and pressure-irregularities are produced by the interaction of the different densities; the fronts, much modified within the pressure-systems, are the immediate cause of most of the bad weather in the regions they reach. In the several seasons air-masses (or groups of air-masses) cover more or less definite areas determined by the general circulation of the atmosphere, and the fronts between them are in localized belts, but both the air-masses and the fronts are subject to wide oscillations like everything atmospheric. Figs. 4 and 5 show important frontal belts, the sources of most of the major disturbances responsible for the bad weather of large regions of the north hemisphere; but in view of their oscillations, and also of the inadequacy of the observations on the oceans where the main fronts lie, the positions shown can only be in some degree arbitrary; and the fronts are often absent.

The great frontal divides are the 'intertropical', the 'polar', and the 'arctic'. The first is the divide between the tropical air-masses of the two hemispheres, or the zone of convergence of the NE. and SE. trades; in view of the structural differences between it and the fronts of higher latitudes it is now often called the intertropical convergence (ITC) or convergence zone (ITCZ) rather than intertropical front (ITF). The polar and arctic fronts are the divides in each hemisphere between the tropical, polar, and arctic air-masses.

The terms winter, spring, summer, and autumn denote particularly the seasons of temperate latitudes, but it is convenient to use them also for low latitudes in an astronomical sense, referring to the position of the sun in relation to the hemisphere concerned.

FIG. 6. Place-names mentioned in the text. For Belgian Congo see Fig. 23, East Africa, Fig. 26, South Africa, Fig. 38.

PART II

AFRICA

CHAPTER III

GENERAL FEATURES

AFRICA, alone of the continents, extends to almost equal distances north and south of the equator. In the south it projects far into the ocean remote from other lands, but in the north-east it joins Asia, and its climate is controlled largely from Asia. Yet in spite of this external control similar series of climates can be traced northward from the equatorial belt of heat and moisture to the Mediterranean Sea, and southward to the Cape of Good Hope. The Sudan has its counterpart in Rhodesia, the Sahara in the arid tracts of the Kalahari and South-west Africa, the Mediterranean coast in the south-west of the Cape Province.

The continent lacks those extensive mountain-ranges that are effective elsewhere as climatic barriers. Gradual transitions take the place of the abrupt changes of climate to which the Andes, for example, give rise. Africa, however, has vast areas of plateau, especially in the south and east, at an altitude of more than 3,000 feet, with a dry and invigorating climate, well suited for European settlement even in latitudes which are usually unhealthy near sea-level.

OCEANIC CONDITIONS

The west coast of North Africa is washed by the Canaries Current, a cool current, owing partly to the direction of its flow from north to south to feed the North Equatorial Current, partly to the upwelling of cool water along the coast under the influence of prevailing offshore winds; the temperature of the surface of the sea at Mogador has been observed to be 60° while 20 miles from shore it was 70°. The effect of the Canaries Current can be recognized from the Strait of Gibraltar to lat. 12° N. in February and 17° N. in August in the low temperatures, frequent fogs, and scanty rainfall of the coast. The conditions of coast and interior are very different,

especially in summer, for in August the temperature of the sea does not exceed 70°, while the arid sands inland may reach 160° under the blazing overhead sun.

The Benguela Current south of the equator corresponds to the Canaries Current in the north, and it is still more prominent in its climatic effects, which are in evidence from the Cape of Good Hope almost to the equator. The coolest water is off the south of South-west Africa, where the sea-surface temperature is below 55° in August, 57° in February. A cool foggy seaboard, much of it an almost rainless desert, is, in part at least, the result of these oceanic conditions.

Between the Canaries and the Benguela Currents the warm waters of the east-going Guinea Current, with temperature over 80°, bring excessive heat and humidity to the coast between the Gambia River and Cape Lopez in summer, Sierra Leone and Cape Lopez in winter.

The currents on the east of Africa are in striking contrast, having surface temperatures much higher than those on the west coast. In the South Indian Ocean a wide Equatorial Current flows from east to west, centred on lat. 15° S. to meet the African coast about Cape Delgado, and thence spreads north and south, north to the equator in winter and much farther in summer, south all the year as far as Cape Agulhas; part of it washes east Madagascar. This equatorial water is warm, its temperature ranging in July from about 78° at the equator to 64° off the south of Africa, in January from about 82° to 70°. Thus the sea is about 10° warmer on the east than on the west of south Africa.

North of the equator the currents are largely controlled by the monsoons of south Asia. In summer the Equatorial Current which swings north from Cape Delgado is driven forward by the SW. monsoon as the very strong and well-marked East African coast Current, which continues past Arabia to the head of the Arabian Sea, its speed frequently attaining 4 knots near the equator, 7 knots off Somalia. The water is very warm, the surface temperature being 82° or higher in most of the ocean north of the equator, and up to 85° over large areas in April and May. Exceptionally, two areas are cooler—off Arabia where the surface is 5° cooler than on the other side of

the Arabian Sea (in August that sea as a whole is about 5° cooler than the Bay of Bengal), and off Somalia where it is about 5° cooler than in the open ocean. The cause in both places is the upwelling of cool water under the coasts; the SW. winds blow almost along-shore and the surface water, moving, as is usual, about 45° to the right of the wind, edges away from the coast and is replaced by water from the cooler layers below, a movement which is strongest round lat. 10° N. This cool water is an important factor in the aridity of Somalia and south Arabia and the frequent fogs off the coasts. Part of the coastal current diverges east and south-east from Somalia with a speed up to 7 knots to form the SW. Monsoon Current, which crosses the ocean between Ceylon and the equator to Sumatra.

By November the winter monsoon is established and the ocean current is reversed, the surface water being driven south-west by the NE. winds; off East Africa it goes as far as the equator; the coastal water is about 3° cooler than the ocean.

In February, although the NE. monsoon is still strong, the current begins to set north-east along the African coast, and a clockwise circulation is established in the Arabian Sea, to be strengthened later under the SW. monsoon. During the months February to April the water is only slightly cooler off Somalia than in the open ocean.

The Red Sea is very hot in all seasons, with surface temperature in January 72° in the north and 78° in the south, and in July 80° and 89°, but the effect on the coasts is greatest in winter; on summer days the water, hot though it is, even exerts a cooling influence on the still hotter sun-baked desert coasts. But the Red Sea is too narrow to have more than local influence. The Mediterranean, on the other hand, is a major control on the meteorology and climate of all the north of Africa. In winter the warm, moist air over the sea engenders low atmospheric pressure, and the weather of the surrounding coasts is mild and rainy. In summer the sea does not heat up so much as the land and the high pressures normal in the sub-tropics spread over it; the great extent of the Sahara is largely due to this fact. The annual range of temperature of the sea-surface is considerable both in the Mediterranean,

25°, and in the Red Sea, 15°. In autumn the Mediterranean retains much of its summer heat, but by spring it has cooled considerably; autumn is notably warmer than spring in the Mediterranean lands.

PRESSURE AND WINDS (Figs. 7*a*, *b*, *c*)

In the northern winter (Fig. 7*b*, January) the cooling of the middle and north of Asia and North America draws the sub-tropical high pressures far north, cold continental anticyclones of great size and intensity building up to form the most prominent features in the isobars of the hemisphere. A 'bridge' of moderately high pressure connects them over the North Atlantic; but between it and the anticyclone over Asia is the Mediterranean Sea with relatively warm, moist, air and a resulting tendency to low pressures; the high-pressure bridge therefore takes a position not over, but to north and south of the Mediterranean, over Europe and over the north of Africa where the pressure is highest on the snow-covered Atlas Mountains and the plateau of Algeria. Between the two branches is the Mediterranean 'lake' of low pressures, the path of many depressions, which give variable westerly winds on the north African coast. Like the Mediterranean, the Red Sea interrupts the high pressures, and a shallow trough extends north over it to the east Mediterranean; this, together with the presence of a small anticyclone in south Arabia, results in the Red Sea having NNW. winds in the north, SSE. in the south, the divide being about lat. 20° N.; severe, though short, storms of wind, rain, and thunder occur at the discontinuity.

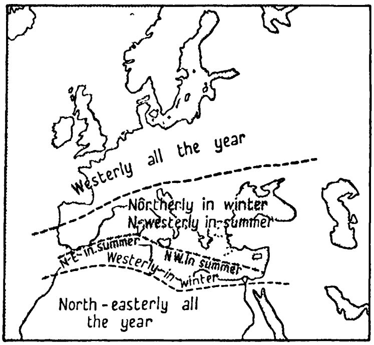
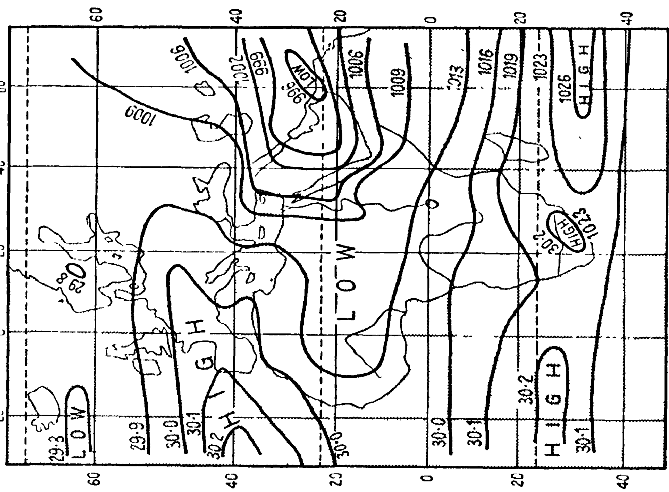
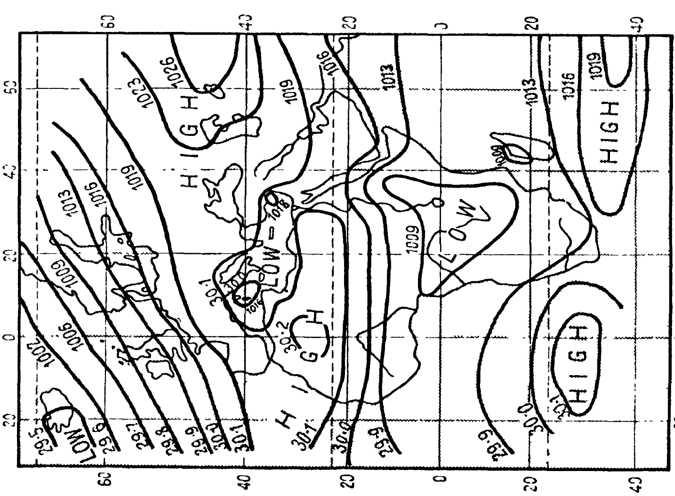


FIG. 7*a*. General winds over Europe and north Africa.

The equatorial trough is south of the equator, with its intertropical convergence on the tropic on the east coast, whence it runs north-east over Madagascar into the Indian Ocean,



July.



January.

FIG. 7*b* and *c*. Mean isobars.

and on the other side north-west through the Belgian Congo to the Gulf of Guinea where it is anomalous in remaining north of the equator, a result of the Guinea lands being warmer than the cool South Atlantic even in winter. South of the intertropical convergence the mean pressure rises to the high pressures of the sub-tropics, centred on the Atlantic about

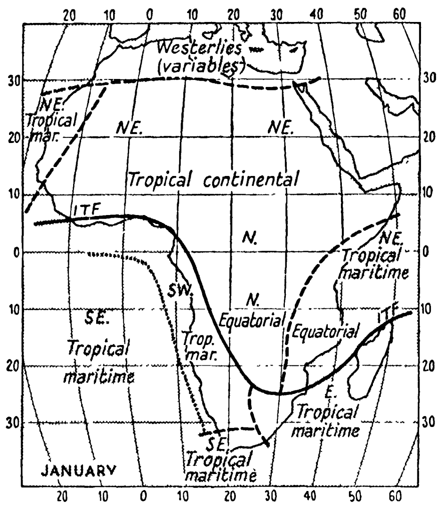


FIG. 8. Dominant air-masses in January; the general wind-directions are indicated by large letters.

30° S., in the Indian Ocean 35° S., and connected by a belt just south of the Cape.

Three main air-masses stream southward from the sub-tropical high pressures, the NE. trade on the Atlantic, the harmattan with a similar direction in the interior as far east as Abyssinia and the Rift valleys, and the NE. monsoon east of the Rift valleys and in the Indian Ocean (Fig. 8, Jan.). The first of these, the NE. trade, consists of maritime tropical air; it sweeps south, dry and cool, and notably constant as far as Liberia. The harmattan also consists of tropical air, but it is of a strongly continental type, dry, hazy, and often dusty as far as the equator, beyond which, having acquired heat and moisture from the forested tropics with their innumerable rivers and swamps, it is damp and rainy when it interacts

frontally with the still damper air on the east. The NE. monsoon originates over Asia and the Pacific. Its northern section, coming direct from the south of Asia, has only a short sea-passage, and advances, dry and rainless, over the arid steppes of Somaliland, but south of the equator the air is hot and moist after its long passage over the equatorial Indian Ocean, and provides the south-east of Africa with most of its rain.

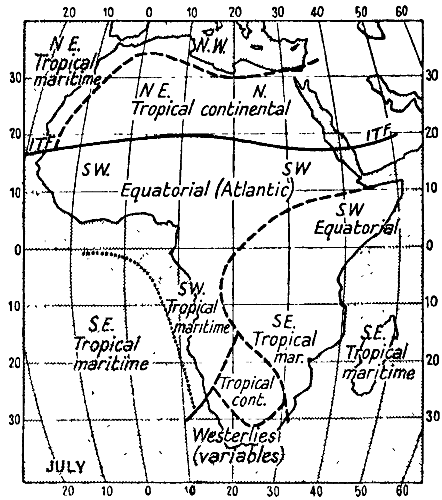


FIG. 9. Dominant air-masses in July; the general wind-directions are indicated by large letters.

South of the intertropical front two main air-masses, both maritime tropical, are dominant. On the west, the SE. trade blows all the way from the Cape to the equator, but it is deflected into a SW. wind on the coasts north of the Orange River; its maritime tropical air is damp and often foggy over the cool Benguela Current, but rainless. On the east of the continent the damper, but still not very moist, SE. trade gives summer rains to Natal and the south-east of the Cape Province.

In the northern summer (Fig. 7*c*, July) Africa north of the equator is dominated by the North Atlantic anticyclone on the west and the monsoonal low pressures of south Asia on the east. The former is centred west of Gibraltar and spreads east over central Europe and the Mediterranean Sea, the

latter over Baluchistan with a vast but shallow trough extending west to cover almost the whole of north Africa except the north-west littoral; in July the intertropical front trends

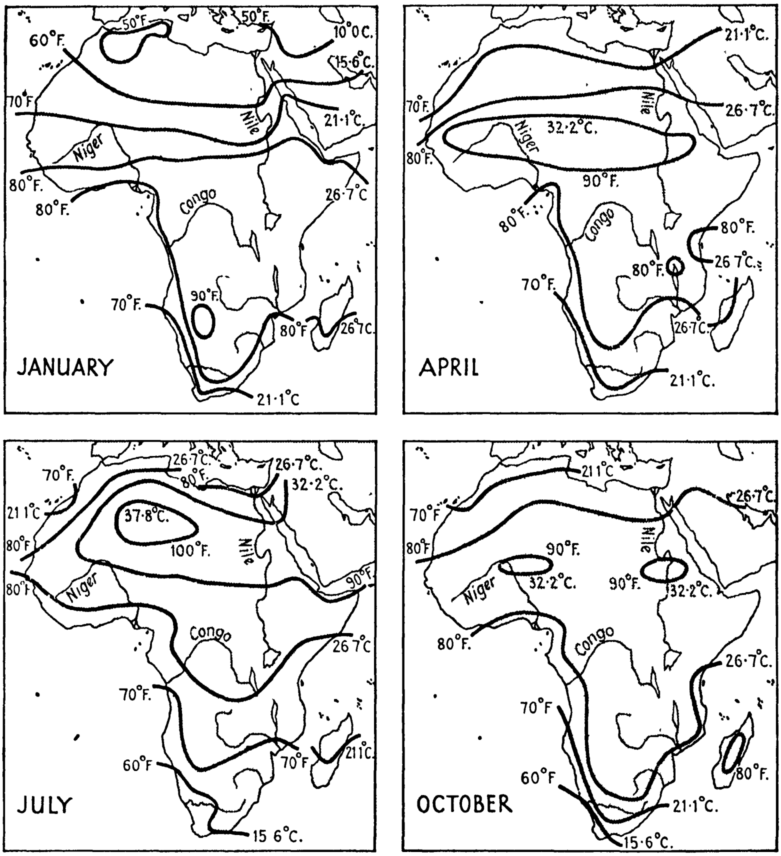


FIG. 10. Mean isotherms.

south-west from Arabia to the north of the Sudan and thence west to Cape Verde. A barometric gradient for moderately strong N. winds covers the region from the Red Sea to the Nile, west of which pressure is more uniform for NE. winds (but local effects give strong winds by day). North of the intertropical front the dominant air-mass (Fig. 9) consists of tropical air of a very pronounced dry, continental, character,

with fresh N. winds in Egypt and NE. between Egypt and the Atlantic. On the Atlantic and its coasts from Portugal to Cape Verde the NE. trade carries maritime tropical air.

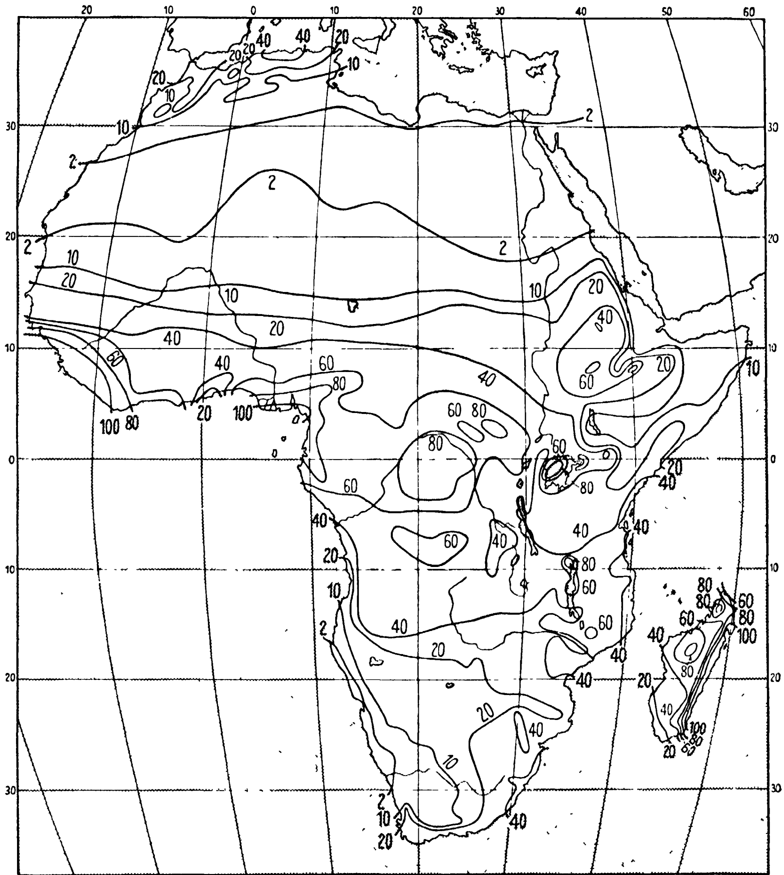


FIG. 11. Mean annual precipitation (compiled from official sources).

South of the intertropical front the source of the air supply is far distant in the high pressures of the sub-tropics about 30° S., with their prominent centres on the South Atlantic and Indian Oceans and a less prominent one on the south-east of the continent; the two main air-masses, both of maritime tropical air, are carried equatorward by the SE. trades of the

two oceans. On the Atlantic the trade blows as in January, and is deflected to come from SW. on all the thousands of miles of coast between the Orange River and Cape Verde; as far as the equator it retains its tropical characteristic of low

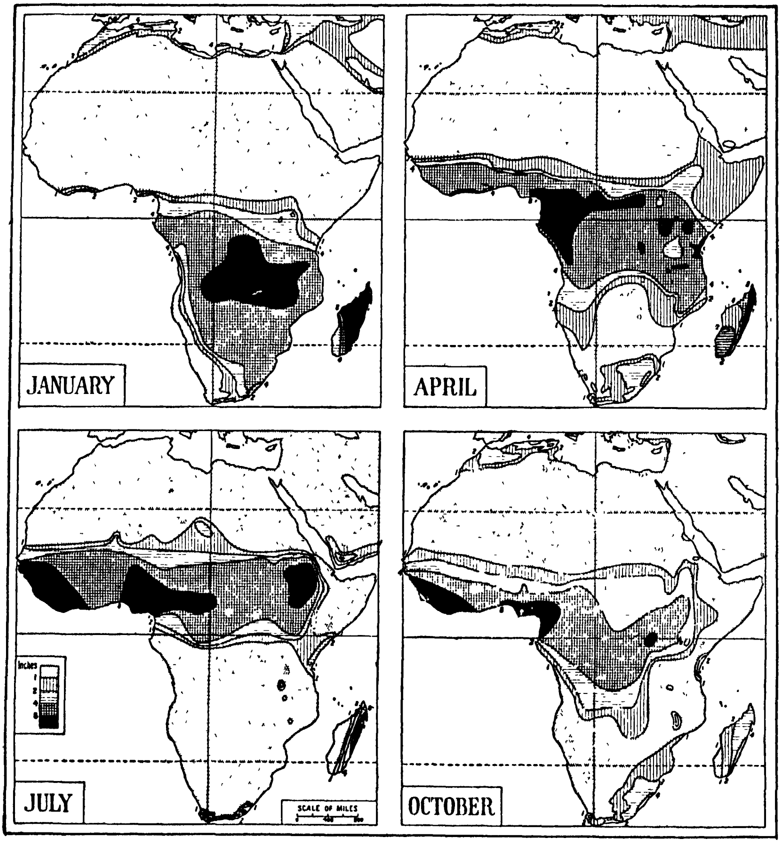


FIG. 12. Mean monthly precipitation.

vapour-content and gives very little rain, but beyond the equator, having acquired abundant moisture from the warm ocean currents, it reaches the land hot, damp, and rainy. The air-stream which crosses the coast between the Congo and Nigeria advances over the continent, probably to the N. Indian Ocean and even into south Asia, distributing the summer rains of the Sudan and the more copious downpours of Abyssi-

nia which feed the Nile flood; the aridity of Eritrea and Somaliland east of Abyssinia and the plateau on the south may be largely a rain-shadow effect. In and west of Cameroons the south-westerlies are sultry, hot and moist, and give the Guinea lands their heavy rains, which decrease in amount and duration towards the north.

The SE. trade of the Indian Ocean blows almost along the African coast, changing direction with it and becoming, north of the equator, the hot, moist SW. monsoon of the North Indian Ocean and south Asia. The interior of Africa has southerlies from the sub-tropics, dry and rainless to the equator, beyond which they merge with the rainy SW. winds in the Sudan.

The extreme south of the Cape Province is under the stormy westerlies, the rain-givers of the small but valuable agricultural lands round the Cape Peninsula.

Temperature

Africa is the hottest of the continents in respect of the mean annual, the summer, and the winter temperatures (Fig. 10). Especially is this so in the northern summer when vast expanses of the Sahara have the highest temperature on the earth for such great areas. Africa is the only continent in which the 50° isotherm (sea-level) never appears. The greater part of the continent has more than 9 months with means above 70°.

A distinction which will be frequently referred to, particularly in East and South Africa, is that between the coastal plain and the interior plateau. In general, the coasts within the tropics are enervating and unhealthy owing to the monotonous moist heat (but the west coast of South Africa is exceptional in being so arid as to be mostly desert). The plateau is less rainy and much more healthy since, although the days are hot, the air is dry, and moreover the cool fresh nights afford welcome relief for European residents; the seasonal range of temperature also is much larger on the plateau.

Rainfall

The mean rainfalls for the year, and for January, April, July, and October are shown in Figs. 11 and 12.

CHAPTER IV

MEDITERRANEAN AFRICA

THIS region comprises Africa north of the Sahara, the meteorological divide being the axis of the sub-tropical high pressures in winter about lat. 30° N. Of its two main sections the western, which extends east to Tunisia, will be described first. It includes lands of very varied relief: the coastal strip on the Mediterranean with a true Mediterranean climate; the plateau of the Shotts, 3,000 to 4,000 feet above the sea, with a steppe climate; the ranges of the Atlas on the north and the south of the plateau, in general exceeding 5,000 feet, and in Morocco 12,000 feet, snow-covered most of the year on the higher seaward slopes; a small area with almost Saharan conditions south of the Atlas (and in parts of the plateau of the Shotts); the plains and plateau on the Atlantic side of Morocco. The climates of the whole region are of the Mediterranean type described in Chap. XXX, but with large local modifications.

The Atlantic coast of Morocco is washed by the cool Canaries Current, important in keeping the summers notably cool for the latitude (Fig. 13, Mogador); the temperature of the sea-surface decreases southward from Cape Spartel, and is lowest off Cape Ghir; the mean air temperature in July is below 70° on much of the coast. In summer, May to September, the NE. trade blows strongly and with little intermission save for the alternating land- and sea-breezes; this is the hot dry season with clear air, high evaporation, bright sunshine, very little cloud or rain. But near the coast the Canaries Current is responsible for much cooler days with small diurnal range of temperature, high humidity, heavy dews, and fairly frequent fog and low cloud, useful in alleviating the drought which afflicts the rest of the lowlands, the south of Morocco having hardly a drop of rain from April to September. The mountains have some rain in summer.

In winter the westerlies are dominant, with their usual variable winds and weather and considerable precipitation, often heavy at the cold fronts of depressions (many of which originate in a semi-permanent front off the coast and travel north-

east). Mean temperature is about 18° lower in January than in July on the coast, 30° lower inland, and frost and snow occasionally occur except in the south; snow is often deep on the Atlas Mountains (see table, p. 43, for temperatures).

The scirocco of continental tropical air, hot, very dry, and dusty from the Sahara, is an unpleasant intrusion, especially in spring, here as in other Mediterranean lands.

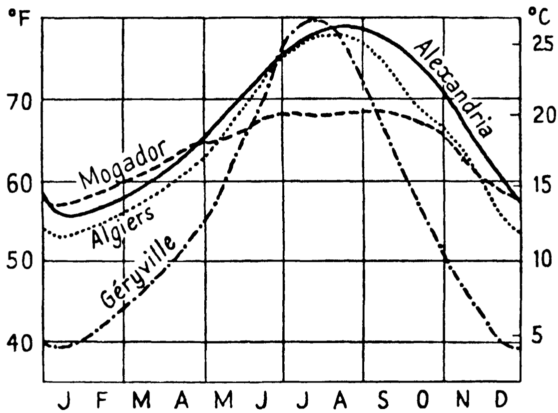


FIG. 13. Mean temperatures.

East of the Strait of Gibraltar the summers are warmer, the sky being almost cloudless (mean cloud at Algiers 3 tenths) and the sunshine powerful. On the Algerian coast the mean temperature of August, the hottest month, is about 75° (Fig. 13), but the fresh NE. winds from the sea prevent excessive heat. In winter the weather is controlled by depressions passing along the Mediterranean, which give SW. winds, with cloud (mean at Algiers 5 tenths), moist air, and rain; 80 per cent. of the rain falls in the winter half-year (Fig. 14). The mean January temperature is between 50° and 55°; frost is very rare. The sheltered valleys of the Tell such as the Mitidja have the best type of Mediterranean climate for agriculture, and are famous for orange groves and vines. The mean annual precipitation exceeds 20 inches everywhere, being least in the west in the lee of Spain, and exceeding 60 inches in Khroumirie on the north slopes of the mountains, which have much snow in winter and bear extensive forests of cork-oak, and

above them cedars. The precipitation is very variable; Algiers has recorded extremes of 16 and 51 inches in a year. The ranges of the Djurjura often rise snow-clad behind Algiers in winter, but snow falls on only 1 or 2 days a year on the coast.

The steppe climate of the plateau of the Shotts is the result of altitude and continentality, the effect of which is increased by the barrier of the Atlas ranges to seaward. A large range of temperature is characteristic. Winter is often bitterly

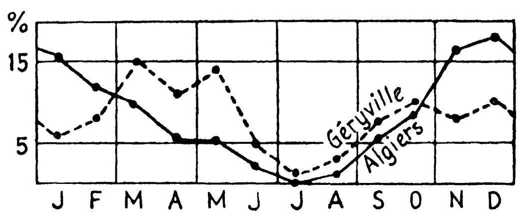


FIG. 14. Mean monthly precipitation, percentage of annual total.

cold, dry N. winds sweeping across the open plains at a temperature well below freezing-point, sometimes with severe snowstorms. Géryville (Fig. 13) has 84 days a year with frost, and has recorded a minimum of 9°. Summer days, on the other hand, are as hot as at sea-level, often hotter, for the clear air gives free passage to the rays of the unclouded sun; Géryville has recorded 108°, the land is parched and the mirage mocks the traveller; cool nights follow the hot days, the diurnal range of temperature reaching 30°. The precipitation is 10 to 20 inches, with a spring maximum generally (Fig. 14, Géryville), due partly to cyclonic activity partly to local convection, and heavy thunderstorms, most in autumn and spring, add to the total; the low temperature of winter and the steady northerly winds of summer are adverse to heavy precipitation. The scanty precipitation, high evaporation, and strong winds are hostile to trees; alfa grass is common and the drier tracts are very poor steppe.

The Saharan Atlas has more precipitation than the plateau and is even forested in places, including the massif of the Aurès. The rain is the source of much of the underground water which supplies the oases of the neighbouring Sahara,

and the possibility of using it for direct irrigation of parts of the desert has been considered. The ranges form a sharp climatic divide; looking north in spring we see the green steppes of the plateau, but at our feet on the south the sands of the Sahara stretch away to the horizon. Biskra has most of its rain in winter, but the scanty total, 8 inches, and the large range of temperature, diurnal and annual, class it rather with the Sahara than the Mediterranean.

The eastern section of Mediterranean Africa, including the north of Libya and Egypt, differs from the west in its lower latitude, its more continental position, its low relief, and the absence of a mountain barrier against the Sahara. Though the midday heat is mitigated by the strong sea-breeze the summers are very hot, 105° being recorded in most years. The winters are considerably warmer than on the coast of Algeria, the January mean being about 57°; snow is almost unknown. The mean rainfall is scanty, at Tripoli 16 inches, Benghazi 11 inches, Port Said 3 inches. The rain falls in winter but reaches only a narrow littoral—Alexandria has 8 inches, Cairo only 1 inch. The prevailing summer winds are between W. and N., those of winter between SW. and NW. The sea tempers the summer heat for a short distance inland (as shown by the curves for Alexandria and Cairo, Fig. 20), but desert conditions reach the coast in many places. Autumn is considerably warmer than spring, as everywhere on the Mediterranean.

Throughout this region the scirocco, with its hot dry blasts and dust from the desert, is a scourge all the year but mostly in spring.

TEMPERATURE DATA FOR REPRESENTATIVE STATIONS

		Mean daily extremes				*Mean monthly extremes*				
	Alt.	*January*		*July*		*January*		*July*		*Absolute*
	Feet	*Max.*	*Min.*	*Max.*	*Min.*	*Max.*	*Min.*	*Max.*	*Min.*	*extremes*
Casablanca	131	63	44	80[1]	63[1]	72	35	93	56	103, 27
Marrakech	1,542	66	40	101[1]	68[1]	77	31	114	61	117, 27
Oran	171	61	45	84[1]	69[1]	70	38	95	62	110, 31
Algiers	194	59	49	83	70	67	41	97	64	112, 28
Tripoli	56	60	47	86[1]	73[1]	68	40	98	66	109, 35
Alexandria	105	65	51	87[1]	74[1]	72	44	91	69	111, 37

[1] August.

CHAPTER V
THE SAHARA

Pressure and Winds

The Sahara, largest of the trade-wind deserts, covers a vast area in North Africa from the Atlantic to the Red Sea, an area, however, which is only part of the whole desert expanse that includes much of south-west and central Asia. Except near the coasts the climate is fairly uniform, allowance being made for altitude which ranges from below sea-level to above 10,000 feet. Its main features are imposed by the harmattan, the continental trade-wind, which sweeps across between the sub-tropical high pressures and the equatorial low, that is to say, in summer from the Mediterranean to about lat. 17° N., in winter from lat. 30° N. to the Guinea coast and central Africa. The true Sahara is between the inner of these limits, where the harmattan is dominant all the year.

The harmattan consists of continental tropical air, originating in subsidence in the sub-tropical high pressures so that it is warm and dry; it blows as a moderate or strong wind, from north in the east of the Sahara, from north-east in the west, but falls calm on the surface at night. Representative data for the interior (In Salah) and the zones on the north and south are:

Mean Percentage Frequencies of Wind Directions

		N.	*NE.*	*E.*	*SE.*	*S.*	*SW.*	*W.*	*NW.*	*Calm*
Touggourt	Jan.	8	14	14	7	3	19	24	10	2
	July	4	11	37	19	12	10	3	5	—
In Salah	Jan.	12	44	13	3	3	6	3	3	13
	July	6	41	30	7	2	6	3	1	5
Bilma[1]	Jan.	5	29	6	—	—	—	—	—	60
	July	1	5	16	4	4	2	5	4	59
Port Étienne[1]	Jan.	37	21	23	2	0	1	4	8	4
	July	38	15	3	0	0	1	6	33	4

[1] Mean of observations at 0800 and 1800.

The harmattan becomes hotter and drier in its passage over the torrid sands; there are very few plants to transpire vapour into the air, pressure-irregularities rarely give rain; and though the air rises vigorously by convection from the hot

surface its ascent is checked before dew-point is reached by its own rapid adiabatic cooling and by the inversion of temperature which usually forms an effective ceiling a few thousand feet above the ground and precludes the large-scale overturning which would be required to give precipitation. Hence the air gets ever hotter and therefore drier, so dry in the daytime that wood warps and splits and leather hardens. At In Salah the mean relative humidity falls to 25 per cent. in summer and is only 56 per cent. in winter. Fortunately the vigorous evaporation from any water reduces the heat, and the wet-bulb thermometer is often 40° or more lower than the dry-bulb on summer days, its maximum rarely exceeding 85°; man can live, thanks to this cooling by evaporation, but he must drink about 10 pints of liquid a day; some desert animals are adapted to dispense with water, others satisfy their requirements from dew.

Cloud, Precipitation

Sunshine is almost continuous throughout the day. The sky is nearly cloudless, with less than 1 tenth mean cloud-amount in the east and rather more in the west, but even the Atlantic coast has only 4 tenths, its more abundant cloud being an effect of the cool ocean current off the coast.

Rain is very scanty. The mean total is less than 2 inches a year, and less than 1 inch in the central expanses; Cairo has 1·1 inches, and in the Nile valley to the south as far as Berber the smallest shower is rare; the Atlantic and Red Sea littorals have rather more. In the north of the Sahara the rain is in the winter half-year, associated with Mediterranean depressions; in the south it is summer rain on the fringe of the monsoon and can be heavy. As in all deserts the rain is extremely variable; Ouargla, Algeria, has had 8·3 inches in a year after years without any; In Salah gets one shower, which may be very heavy, in about 10 years. 'Mean rainfall' is a term of little practical significance. Threatening clouds sometimes pass over, but the curtains of rain that fall from them are evaporated in the thirsty air before they can reach the ground. The rare torrential showers—giving as much as 2 inches in regions that have had no rain for years—are due in many cases to unusually active convection when the normal inversion

ceiling breaks down. The wadis rush along brim-full, and much damage may be done, but the underground water-supplies on which life depends are renewed.

Lasserre (*Les Territoires du Sud de l'Algérie*, i, p. 254), illustrates this:

> On Jan. 15, 1922, at 8 p.m. a hurricane, followed by torrential rain, descended on the Tamanrasset district. The roofs of nearly all the houses fell in, and the natives took refuge in the Laperrine and Le Père de Foucauld forts. The flood swept away the huts and the gardens by the side of the wadi. The rain continued on Jan. 16, the wadi had overflowed and was rushing along with the speed of a galloping horse. At 5 p.m. the outer wall of the Père de Foucauld fort collapsed and buried 22 people, who were dug out in the icy rain; 8 were found to be dead and 8 wounded. On Jan. 17 the rain was less heavy, the wadi went down and the weather cleared. Snow could be seen on the neighbouring mountains.

However, not all rain in the desert is of this violent character, even drizzle or light rain occurring.

The mountains are more favoured than the plains. The southern groups of Aïr and Tibesti get considerable rainfall every summer, often in thunderstorms of great violence which send sudden floods down the wadis. The unwary, both animals and men, who happen to be in their path, even far away from the storm area, may easily be swept away. The Ahaggar, farther north, is fortunate in getting a share both of the summer rains from the south and the winter rains (and occasional snow above 8,000 feet, but it soon melts) from the north, and contains some running streams in its deep valleys. Probably the annual mean is about 10 inches in the Ahaggar and Aïr, but much less in Tibesti which is in the heart of the desert. Many summits are snow-capped in winter, and snow may fall heavily even on the lowlands of the north of the Sahara, but does not lie long.

Dust

Dust is one of the worries of life in the Sahara as in all arid lands. Even a light breeze blowing from sand-dunes carries its load of fine particles, and travel is often rendered unpleasant, and even entirely stopped, by clouds of dust swept along by the strong winds both horizontally and in whirls (dust-devils).

Sometimes in a real dust-storm, a simoom, the hot air is filled and darkened by thick dust-clouds. Many Egyptian proverbs are suggestive of the terrible prevalence of eye diseases which are largely due to the ubiquitous dust—'dimness of sight is better than blindness', 'the desire of the blind man is a basketful of eyes'. Strong southerly winds are specially hot and unpleasant, and have everywhere their local names, scirocco, chili, khamsin.

Temperature

The outstanding feature is the summer heat. The overhead sun pours down its rays through the dry air from the deep-blue cloudless sky during the long days, and bakes the naked dry sand and rock till they are too hot to touch; a temperature of 172° in the surface sand has been noted. But the excessive heat does not penetrate far; with a surface reading of 131° the temperature 3 inches below was found to be only 81°, so that animals find a tolerable eco-climate by burrowing. The surface air resting on the torrid sand is heated intensely since ascent, with replacement by cooler air, is checked by the inversion of temperature aloft; In Salah had a spell of 45 days in 1931 with mean daily maximum 118°, absolute maximum 127°, and absolute minimum 70°. The highest reading ever recorded on the globe under standard conditions was 136° on 13 September 1922 at Azizia, 25 miles south of Tripoli, where 110° is reached in each month from May to September every year; the heat here is intensified by a local föhn effect, the air from the sun-baked desert on the south descending from an upland of 2,000 feet.

The Sahara is indeed a furnace of heat on summer days, but the clear, dry air also favours rapid cooling after sunset to a minimum 30° or 40° below the day's maximum; but the temperature is still 70° or 80°, so that the nights are cool only by comparison with the Saharan days:

> Suddenly, after hardly any twilight, the sun rises into the clear sky. In this dry atmosphere its rays are already scorching in the early morning, and under the influence of the reflection from rock and sand the layer of air next the ground is heated rapidly. There is no active evaporation to moderate the rising temperature. After 9 o'clock the heat is intense, but goes on increasing till 3 or 4 in the

afternoon, when the quivering mirage is sometimes seen. It cools slowly towards evening, and the sun, just before it sets, suffuses the cloudless sky with a glow of colour. In the transparent night the rocks and sand lose their heat almost as rapidly as they acquired it, and the calm of the atmosphere, which is so still that a flame burns without a tremor, also favours the cooling of the air. We shiver with cold and it is no uncommon thing in winter to find water on the surface of the ground frozen in the morning (SCHIRMER, *Le Sahara.*)

The mean daily range is:

	J.	*F.*	*M.*	*A.*	*M.*	*J.*	*J.*	*A.*	*S.*	*O.*	*N.*	*D.*	*Year*
Dakhla	30	33	34	36	36	33	31	31	29	29	29	29	32
In Salah	29	32	32	33	33	34	34	32	33	32	30	29	32

But the range in the heart of the desert may exceed 55° on individual days. In Borku the mean daily maximum in May is about 112°, mean daily minimum 67°, daily range 45°. Far higher figures may occur, as early travellers found; at Toro, south Bornu, on 15 May 1871 the temperature range was 57°, from 59° at sunrise to 116° at 1400; and on Christmas day 1879 Rohlfs and Stecker noted a minimum of 31° and maximum 99°, range 68°.

The Saharan winter is comfortably cool, the mean temperature in January ranging from 50° in the north to 70° in the south. The nights can be cold in the north, with temperatures below freezing-point, even below 25° in the Libyan and the Algerian Sahara; Touggourt has an average of 6 nights a year with frost and occasionally the irrigation channels have a thin covering of ice. But frost is unknown in the south, the coldest weather being during spells of polar air from the north (p. 67). The large range of temperature in the north is illustrated in the neighbourhood of Azizia, the scene of the globe's record heat mentioned above, in February 1949:

TRIPOLI, Feb. 11.—Ninety-five people died of cold and many are missing after the great snowstorm which has swept the deserts of north-west Libya. Twelve-foot snow drifts blocked communications and isolated entire villages for three days. In one village five children and their mothers died on their way from a school. British troops were employed to open roads and take food and clothing to the worst hit areas. (*The Times.*)

Absolute extreme temperatures in the Sahara are:

	Absolute maximum.	Absolute minimum.
Biskra	121	28
Touggourt	122	27
Azizia	136	27
Tamanrasset	101	20
Bilma	118	27
Port Étienne	114	45

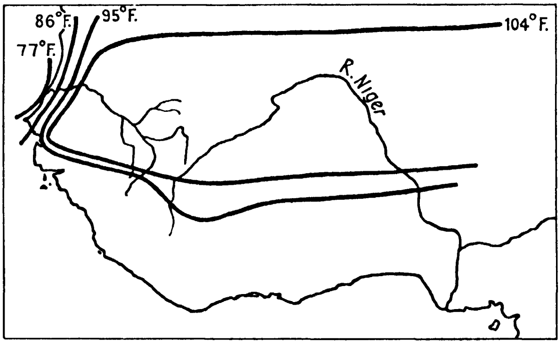


FIG. 15. Mean daily maximum temperature in West Africa, May 1923 (Hubert).

The mean annual range, like the mean daily, is large for the latitude, about 45° in the north, 30° in the south.

The Atlantic coast of the Sahara, washed by the Canaries Current, is much cooler than the interior in summer, the July mean being 20° less, a result of the vigorous sea-breeze which sets in every day (Fig. 15). Fog and low cloud are fairly frequent as on all coasts washed by a cool current.

The Red Sea coast is distinguished from the interior by its smaller range of temperature and its much higher humidity. At Port Sudan the mean temperature is 95° in August, 74° in February, and the mean annual rainfall is 4·3 inches, most of it in winter when hot winds, moist after a long passage over the Red Sea, meet the highlands under the influence of Mediterranean depressions; part is contributed by copious dews which may equal a shower of rain. Dust-storms, including khamsins, are frequent, and are as irritating as in the interior; their bad, sometimes very bad, visibility often spreads over the Red Sea.

The temperatures are illustrated by the following table (Aden and Berbera are included for convenience):

	January		*July*			
	Mean daily max.	*Mean daily min.*	*Mean daily max.*	*Mean daily min.*	*Absolute extremes*	
Suez .	68	49	98	73	113	35
Quseir .	73	57	92	80	118	39
Port Sudan	81	68	106	83	117	50
Aden .	85	73	94	82	109	61
Berbera .	85	68	107	88	117	52

The excessive humidity is shown by the high wet-bulb temperatures; it is to be remembered that readings above 75° indicate decidedly uncomfortable conditions, and with those over 80° heat-stroke is frequent. The air over the Red Sea to which the following means refer is often carried over the African coast:

MEAN WET-BULB TEMPERATURE OVER THE RED SEA

	Lat. 27° *N.*	*Lat.* 15° *N.*
Jan. . .	61	74
July . .	77	84

On the Egyptian coast north of the tropic the wet-bulb often rises above 80° on summer days.

The Saharan climate is not unhealthy. The summer days are hot indeed, but the air is very dry, and the nights are cool except in the hottest months. It presents a great contrast to tropical Africa where the heat is oppressive by night as well as by day, and is associated with high humidity, a very unhealthy combination for white settlers.

Some references to the Saharan climate will be found in Chapter VII.

CHAPTER VI

THE SUDAN WEST OF LAKE CHAD. THE GUINEA LANDS

THE antithesis of the Sahara is the Belgian Congo and the Guinea coast, where abundant rain throughout the year and constant moist heat maintain the rank luxuriance of almost impenetrable rain-forest.

Between these opposites is a transition region, a belt stretching across the greatest width of Africa, which has rain in summer and well-marked drought in winter, the lengths of the rainy and dry seasons varying with latitude. This is the Sudan, a region of great potential agricultural value, as yet only partially developed and not fully explored.

PRESSURE AND WINDS

The meteorology of the region is fairly simple. On the surface are two dominating air-masses, the northerly harmattan of dry continental tropical air, warm in winter, hot in summer, which comes from the Sahara, and the SW. monsoon of humid oceanic air, an extension of the SE. trade of the Atlantic. They meet in the intertropical convergence, where their interaction with each other, and also with the upper 'equatorial easterlies', produces thick low cloud and heavy rain, sometimes with violent thunderstorms. The position of the convergence is the key to the seasons. The equatorial easterlies just mentioned are a deep layer of easterly winds of uncertain origin above the harmattan and the monsoon; they are deepest, more than 30,000 feet, near the equator, and thin towards north and north-west, the depth varying seasonally; warm and fairly humid, they are thought by some to consist of modified harmattan air, by others to be the usual upper current of the equatorial trough which has come from the Indian Ocean.

In January the convergence is farthest south, in the long tongue of low pressure extending west near the Guinea coast from the main low pressures in south Africa; its northerly position is a result of the land being warmer than the South

Atlantic. Under the returning sun the low pressures deepen and move north, and in March the convergence reaches lat. 10° N., having preceded the sun to the open lands under the clear skies of the interior, which are hotter than the forested lowlands near the coast. Thus in January the dry, rainless, harmattan sweeps over all the Guinea lands, to weaken near the coast where it is sometimes replaced by south-westerlies; but it may cross the coast and continue some little distance over the sea. In the succeeding months the moist monsoon penetrates more and more inland, till in July it covers the whole region. So the extreme north has dry NE. winds during the greater part of the year, broken only by a short spell of south-westerlies in summer, and the aridity precludes agriculture. The coast, on the other hand, has the monsoon almost the whole year; the climate is equatorial, the rain-forest as luxuriant as in the Congo:

WIND DIRECTIONS, MEAN PERCENTAGE FREQUENCIES

	N.	*NE.*	*E.*	*SE.*	*S.*	*SW.*	*W.*	*NW.*	*Calm*
Zinder,[1] Jan. . .	1	20	48	1	1	0	0	0	29
July . .	1	0	1	1	1	5	24	11	56
Dakar,[2] Jan. . .	53	30	7	0	0	1	5	4	0
July . .	9	4	3	2	4	11	46	21	0
Ouagadougou,[1] Jan. .	1	27	23	1	1	1	0	1	45
July .	2	1	2	3	9	45	10	2	26
Accra,[3] Jan. . .	10	9	3	1	0	30	20	19	8
July . .	3	0	0	2	3	57	23	9	3
Lagos,[3] Jan. . .	10	10	4	4	5	27	6	17	17
July . .	3	5	4	3	6	53	9	6	11

[1] Hours of observations: 0800, 1300, 1800. [2] 0700, 1400. [3] 0900, 1500.

Travelling south in July from the west coast of the Sahara, we first meet SW. winds some distance north of the Senegal River; the mouth of the Senegal has south-westerlies in 4 summer months, and the NE. trade or harmattan in the rest of the year; the duration of the south-westerlies increases rapidly to the south; in the neighbourhood of Bathurst they blow for 8 months and in the south of Portuguese Guinea and along the Guinea coast they are dominant throughout the year. On the coast they are in part sea-breezes rather than a true monsoon, for the interior, beyond the reach of the sea-breeze, has longer spells of NE. wind in winter than the coast in the same latitude. In the middle of summer SW. winds reach lat. 20° N.

in the interior, north of the Niger bend. Four hundred miles out to sea, in the Cape Verde Islands, the NE. trade blows for 9 almost rainless months; August to October is the *tempo das aguas*, with south-westerlies, sultry weather, and rain, which justify the name of the group. Fig. 16 shows the migration of the harmattan and the monsoon through the year along the meridian 7·5 W.

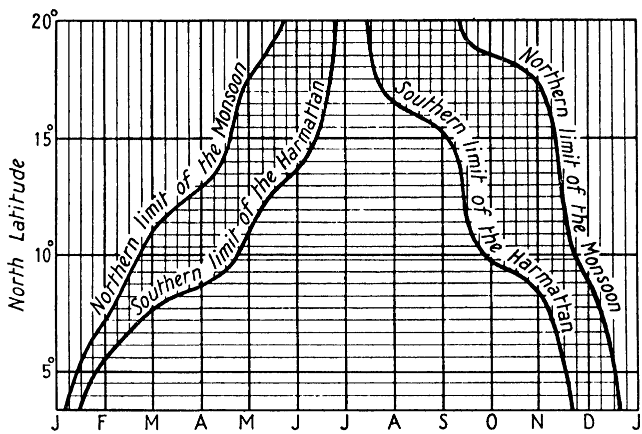


FIG. 16. Migration of wind-systems on long. 7·5° W. in 1935 (Hubert).

RAINFALL

The seasons are distinguished in part by temperature but mainly by humidity and rainfall. The SW. monsoon brings the rain, most of which is associated with the front between it and the harmattan, so that the rain-belt sweeps twice across the region, as the front advances north and again as it returns.

Much of the rain is of the convectional type common in the tropics, falling in heavy thunderstorms in the heat of the day. But spells of cloud and steady rain may last for 24 hours or more with varying intensity. Tornadoes also give downpours, very heavy but short (p. 62). Most rain is not at the inter-tropical convergence itself, but in a belt with a width of about 300 miles, its north edge about 100 miles south of the front; this is the zone of tornadoes. The tract between the convergence and the rainy belt is subject to thick dust-storms in the afternoon where the ground is dusty. South of the main rainy belt the monsoon gives much less rain; near the coast

the monsoonal air-mass often has an inversion of temperature at a height of about 6,000 feet, which prevents much vertical development or heavy condensation, and largely as a result of this August and September form a minor dry season with little rain, most of it drizzle at night and light showers in the afternoon.

The rains are a time of intense life for the plant-world, which wakes from its annual rest with their advent. For the European it is the most unhealthy part of the year. Fever is rife, and any activity laborious in the sweltering steamy heat. The rivers are in high flood and thousands of square miles of the low ground are under water. Unfortunately the district most frequented by Europeans is the coast, the region with the longest and heaviest rains, the pernicious effects of which are increased by the rotting vegetation and slimy ooze of the mangrove swamps. Sierra Leone and the Niger delta have earned the reputation of having climates among the most unhealthy in the world. But the interior of Sierra Leone, particularly the higher parts (and much is elevated), is less unhealthy than the coast, and hygienic measures have already effected great improvement even there, and more may be expected in the future. But a land with a mean annual temperature 80°, a range of only 4° between the warmest and coolest months, and a rainfall over 175 inches, can never be an ideal residence for Europeans.

A description given by Borius of a day in the rainy season in Senegambia is a vivid picture of the conditions over much of the Guinea lands:

The sun rises out of clouds which soon melt away under its rays; the air is fresh and pleasant, with a few puffs of wind from SW., and light white clouds spread fanwise from the horizon and cross the valley, slowly changing form. Soon after sunrise the shade temperature is 80°. The calm air gets hotter, and by 9 a.m. it is unpleasant to walk abroad, even with a sunshade. The wet ground reflects the bright sunshine, and this combines with the high temperature, the moisture-laden air, and the fever germs to make the sunshine at this season so dangerous.

About 10 a.m., in spite of an increase in temperature of perhaps 3°, the heat is still bearable and admits of a little activity. The SW. breeze is beginning but is irregular and seems to be on the point of dying away at any moment. At midday the thermometer is still

rising, and by 1 p.m. it stands at 86°; the sun is hidden at times as a few cumulus clouds cross the sky from south to north, and the surface wind oscillates between W. and SW., but is still very weak. By 4 p.m. the temperature is 88°, the sky is three-fourths clouded, and masses of cloud are piling up on the horizon; the wind often drops altogether. The heat is oppressive, and though after 4 p.m. the thermometer rises hardly a degree yet the heat seems to be increasing, and we are astonished that the thermometer does not show a greater rise. We perspire profusely on the slightest exertion.

At 6 p.m. the sun disappears in thick clouds, which it colours a brilliant copper. It falls calm except for a few puffs from the south and south-west which bring no life and fail to reach the inside of the house, and we have to go out on the roof to try to get a breath of cool air. A little black cloud passes overhead from the south-west, and a few drops of rain fall from it but not enough to wet the ground. We go in again, but the heat indoors is unbearable and we long for a breeze. The water, which is kept in porous vessels, and which seemed cool in the morning, is now lukewarm. There is no need for a hygrometer to show that the air is saturated with moisture. The vapour-pressure is 30 mb., and it is this high humidity that makes the heat so overpowering, although the actual temperature is not excessive.

Nothing can be compared with the feeling of utter prostration that overcomes a European. Though he sits motionless in an arm-chair he perspires as after violent toil; his fatigue is not like what is felt after work, but rather a weakness in the limbs, and especially in the bones—an indescribable discomfort, which precludes all movement, all bodily or mental work, but yet forbids sleep. Clouds of mosquitoes swarm round him and he feels suffocated.

At 10 p.m. it has fallen dead calm. The temperature still continues high and our discomfort becomes greater than ever. We can neither read nor work, for that would require an effort of the will which we are incapable of making; our mental energy is sapped even more than our physical strength. Night drags on in this painful way unless a thunder-storm bursts, with heavy rain, in which case the temperature falls and we feel a welcome freshness in the air. We may form some idea of the painful conditions of life on the Senegal during the rains if we think of the discomfort sometimes felt in Europe just before a summer thunderstorm and imagine that discomfort increased tenfold.

The rainfall decreases from south to north; much of the south-west and south coast has over 100 inches a year, Timbuktu only 9 inches, and at 17° N. the mean is inappreciable.

A rainy month being taken to be one with 2 inches or more of mean rainfall, approximate belts are:

	Number of rainy months	Number of rain-days in a rainy month	Mean annual rainfall (in.)
Coast to 9° N. . .	8–7	20–15	>50
9° to 15° N. . . .	7–4	15–10	50–10
Beyond 15° N. . .	<3	<10	<10

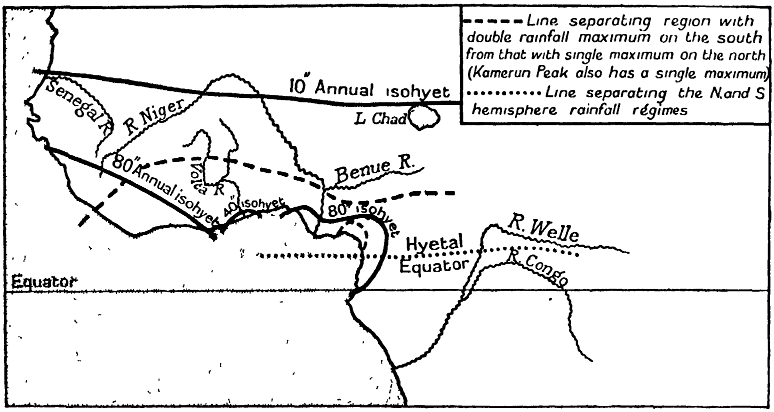


FIG. 17. Significant rainfall lines in West Africa.

No precise limit of appreciable rainfall can be laid down since it is very variable from year to year; rain-gauges are few, and conclusions have to be based on the vegetation. Districts which travellers have reported to be almost bare and apparently rainless have been found later to have an abundant plant-cover. Thus the Sahara is bounded by a debatable belt, too arid for any cultivation, but with enough rain in wet years for good vegetation.

The 10-inch isohyet (Fig. 17) runs almost along the parallel from the mouth of the Senegal to Lake Chad, and not far south are the isohyets of 20 and 30 inches. The country north of about 10° N. has a single short rainy season. Timbuktu has only 2 months, July and August, with more than 2 inches of rain, and the rain varies much from year to year as in most arid countries. South of 10° N. the double maximum is clearly marked except on the south-west coast (Fig. 18).

In the interior November to February is the dry season. Heavy

rains begin in April, and increase to a maximum in June. July and August have less, though still heavy, rain, and September gives the second maximum, higher than that of June (Bismarckburg, Fig. 18). On the coast the régime is similar except that the early maximum is the higher; almost two-thirds of the rain is in April, May, and June; the August minimum is very pronounced, that month being practically rainless (Cape Coast Castle, Fig. 18). Sierra Leone and most of the Liberian coast have a single maximum, the rain increasing steadily

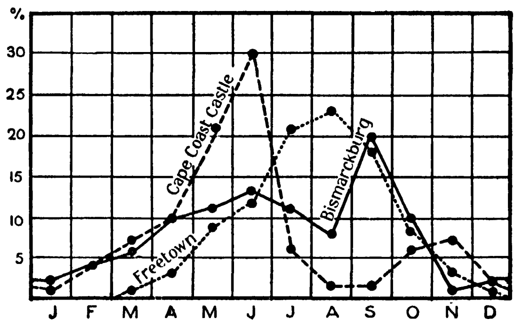


FIG. 18. Mean monthly rainfall.

till August and then decreasing (Freetown, Fig. 18). This difference from the régime up-country in the same latitude results from the strong summer monsoon meeting the elevated coast, most rain falling when the interior is hottest and the monsoon strongest (as on Cameroon Mt., p. 77).

The rainfall is very heavy, exceeding 175 inches in much of Sierra Leone; most of it is in the months April to November. It increases rapidly on the coast southward from the Sahara; Cape Verde has about 20 inches, Bathurst 50, Conakry almost 200 inches. The other notably rainy region, the Niger delta, has two maxima, in June and October, but every month of the year has considerable rainfall. At Akassa the driest month, January, has 3 inches, and all other months over 6 inches; October has most, 25 inches, and the yearly total is 144 inches.

Separating these two very rainy areas is a narrow coastal strip between Cape Three Points and Nigeria with the remarkably small total of about 30 inches (Fig. 17); the interior has more than the coast, 50 miles inland over 50 inches. The prevailing winds are the same on this drier littoral as on each

side, and the main cause of the low rainfall is the presence in summer of upwelling cool water off the coast, caused not by an off-shore wind, for the prevailing wind is SW., but by the pull of the Guinea Current; the tendency to fog supports this view; another fact conducing to low rainfall is that the prevailing wind is parallel to the coast. The increase in the rainfall east of Lagos is as striking as the decrease just described, the total amounting to over 100 inches on the coast of the delta which trends NW.–SE. to receive the monsoon at right angles; the excessive rainfall continues on the delta beyond the mouth of the Niger although the coast changes direction, condensation being increased by the low hills between the Niger and the Cross River, and still more beyond the Cross River by the highlands of Cameroons, where, too, the coast bends southward again. The area of excessive rain does not extend far inland, the mean falling to 50 inches in the delta region about 200 miles from the coast.

The dry season presents a striking contrast after the rains; it is the season of the harmattan, a time of unbroken drought over large areas of the interior. Under the cloudless skies the days are hot or very hot, though astronomically it is winter, but the nights are cool, in part owing to the evaporation, the wet-bulb often falling below 40° in the north of Nigeria. Though cloudless the sky is not blue, nor is the air clear, for it is often charged with fine dust that produces a dismal grey which the sun can hardly pierce; smoke from bush-fires is another source of haze. The harmattan haze consists of minute dust-particles carried up to great heights (15,000 feet or more) as the wind sweeps over tracts of the Sahara covered with fine loose dust, particularly in cold fronts, many of which, hundreds of miles long, come from the Mediterranean or even farther north. The lowlands of Borku, south of Tibesti, are a likely source of much of the dust-haze of Nigeria. The haze can form a thick fog over the coast and the coastal waters between Cape Verde and Cape Lopez, and it is found even to mid-Atlantic. When strong the wind raises coarse sand, and swirls it along in sheets or in revolving dust-devils. The dryness of the harmattan is very prominent, relative humidity falling below 40 per cent.; leaves turn yellow and fall, and

wood splits; the land sometimes dries and hardens so suddenly that the ground-nuts cannot be harvested. Man suffers much discomfort, but, for a time at least, the change from the steamy heat of the rains is welcome.

Representative data of rainfall are:

	Mean annual rainfall	*Number of rain-days*[1] *year*	*month with most*
Freetown . .	151	151	26 (July)
Lagos . .	72	103	17 (June)
Calabar . .	119	173	24 (Aug.)
Zungeru . .	45	90	21 (Sept.)

[1] Days with 0·04 inch or more at Freetown and Lagos, with 0·01 inch or more at Calabar and Zungeru.

Humidity

The mean monthly vapour-pressure on the Guinea coast south and east of Freetown changes but little seasonally, from about 30 mb. (0·9 inch) in winter to 27 mb. (0·8 inch) in summer; on the Atlantic coast north of Freetown it is much higher in summer (28 mb., 0·8 inch) than in winter (17 mb., 0·5 inch). In the interior the dry harmattan of winter has monthly means below 7 mb. (0·2 inch), and the SW. monsoon brings a sudden and very large increase, probably to values higher than on the Guinea coast. Thus the range is much larger in the interior and on the Atlantic coast than on the Guinea coast, and the seasonal change is reversed.

Visibility

Obscurity due to both dry and wet particles is frequent in West Africa. Of the dry types haze, consisting of the fine dust carried by the harmattan, is the commoner (p. 34); it is frequent on land and is often carried a thousand miles or more over the ocean where several layers or horizons of it may be observed from aircraft. The other type of dry haze is smoke from bush- and grass-fires far up-country in the dry season.

Two forms of wet fog occur, shallow inversion-fog at night on wet ground, marshes, or lagoons, and in forests, to be dispersed by the heat of the morning sun before 0900, and the much more extensive sea-fog formed in hot, moist, air passing over cooler water (often present off the Guinea coast) and sometimes carried a few miles inland.

TEMPERATURE (table, p. 61)

Three east–west belts can usefully be distinguished, the modifications due to altitude being omitted.

1. Between lats. 17° and 10° N. (Kano, Fig. 19). Temperature rises rapidly as the sun comes north, to reach monthly means above 90° in April and May, when the heat is Saharan with daily maxima exceeding 110°. The arrival of the monsoon with its heavy cloud and rain checks the rise, and temperature falls fast to a minimum in August, when the mean is 10° lower than in May. In the monsoonal months the weather is sultry and the damp very trying; the daily maxima are lower but the minima much higher than in the preceding months of fierce sunshine. As the monsoon retreats temperature rises again, 2° or 3° in September, after which it falls to a marked winter minimum (January mean 70°). The annual range increases from 10° in the south to over 20° in the north.

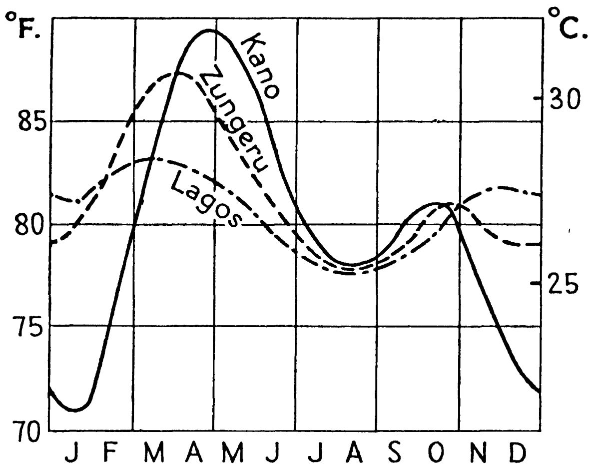


FIG. 19. Mean temperature.

2. Between lats. 10° and 7° N. (Zungeru, Fig. 19). Transitional between belts 1 and 3.

3. The coastal belt (Lagos, Fig. 19). Equatorial in its uniform temperature and humidity through most of the year; the annual range, 4–6°, is much less than up-country, the means of the hottest months, March and April, not much exceeding 80°, and winter being much warmer than in the

north. The coolest months are July and August despite the hemisphere, the monsoon, then at its height, bringing oceanic air from beyond the equator, but no month is really cool.

Fig. 19 also shows the uniformity throughout the region in the monsoon period, July to October. In November to February the coastal belt is much warmer than the interior, and in March to June much cooler. During the monsoon the temperature is highest not in the south, where the fresh winds from the ocean reduce it while importing the humidity which makes it uncomfortable, but in the far interior. In the dry season, on the other hand, the interior is coolest, but even Timbuktu has a January mean above 70°; however, ground-frost is not unknown in the clear nights of the dry season in the far north. The annual range is largest inland, being 23° at Timbuktu and only 6° at Cape Coast Castle; and also the diurnal range which is 31° at Timbuktu in the dry season, 24° in the rains, but at Grand Bassam only 17° in January, 9° in July. The highlands over 2,000 feet, including the Bauchi plateau of Nigeria (which exceeds 4,000 feet) and the Fouta Jalon and other uplands of French Guinea of similar height, are 10° to 17° cooler than the surrounding lowlands.

As in many monsoonal climates the hottest season is just before the rains begin, for the thick clouds of the rainy season screen the sun and the falling drops cool the air—in heavy showers 10° or more. Temperature rises again after the rains. Thus the interior has three distinct seasons, November to January dry and cool, February to May dry and hot, June to October the rains. The natives, enervated by the hothouse atmosphere, are sensitive to the temperature changes and light fires for warmth at night.

Temperature Data for Representative Stations

		Warmest month			*Coolest month*			
	Alt. feet	*Month*	*Mean daily max.*	*Mean daily min.*	*Month*	*Mean daily max.*	*Mean daily min.*	*Absolute extremes*
Dakar	105	Oct.	88	76	Apr.	80	65	100, 59
Freetown	180	Mar.	90	75	Aug.	82	72	101, 62
Accra	53	Mar.	88	76	Aug.	80	71	100, 59
Lagos	10	Mar.	89	78	Aug.	82	73	104, 60
Zungeru	425	Mar.	100	73	Aug.	85	71	110, 52
Bamako	1,076	Apr.	103	77	Aug.	86	71	110, 53
Gao	876	May	110	80	Jan.	87	59	116, 48

It should be noted that the Sahara attains much higher temperatures than the Guinea lands where the clouds and moist air screen the sun. The highest shade temperatures on the Guinea coast do not much exceed 100° and the usual maximum is about 90°. Away from the sea the rains are shorter and higher maxima are recorded; Timbuktu, with summer readings exceeding 118°, approaches the furnace-heats of farther north. But the nights are less cool near the coast than inland; the mean minimum for the year at Freetown is about 70° (abs. min. 62°), at Timbuktu 54° (abs. min. 42°); the sultry nights are among the main discomforts on the coast, where the unhealthiness is due to the combination of excessive humidity and considerable heat, not to excessive heat; at Freetown the wet-bulb is said to have reached 100°, an extremely high reading.

TORNADOES

The best known and most violent storms of the Guinea lands are tornadoes,[1] thunderstorms which often start suddenly, last but a short time, usually less than 2 hours and sometimes only a quarter of an hour, and may do considerable damage on land and sea. They are most frequent at the beginning and end of the rains. Clearly these linear, frontal, disturbances result from the interaction of the surface SW. monsoon, about 5,000 feet deep, and the warm damp equatorial easterlies (p. 51) above, which possibly consist of modified harmattan air. Hence the belt in which they occur swings north and south with the sun, so that their season is March, April, and May and October and November near the coast, May to September up-country. The length of the disturbance is variable; some tornadoes may start with a length of about 10 miles and grow to 200 in Nigeria, where they are longest; some are lines of almost disconnected thunderstorms, and local observation unaided by synoptic charts may fail to distinguish between isolated thunderstorms and a real tornado. They travel at about 30 miles an hour and many retain their individuality for 500 miles. They always advance from east to west.

[1] See Hamilton and Archbold, 'Meteorology of Nigeria and Adjacent Territory', *Q.J.R. Met. Soc.*, July 1945.

The main features for the observer on the ground are the massive clouds seen from afar in the east as the disturbance approaches, with extraordinarily frequent lightning, especially awe-inspiring at night; the violent outrushing squall from the east which sweeps down from the cloud, now nearly overhead, with a velocity occasionally reaching 80 miles an hour in the interior but not usually exceeding 40 near the coast, raising clouds of dust from dry surfaces; and the torrential rain that follows abruptly as the squall ceases, with blinding flashes of lightning and crashing peals of thunder from the cumulo-nimbus clouds towering up 20,000 feet or more (but some tornadoes give little rain). Tornadoes are most violent in the late afternoon, but most frequent at night between sunset and sunrise. They are the greatest risk to which aircraft are exposed in the region.

They are rare south of French Cameroons, but are not unknown even on the lower Congo River. Few travel far over the sea, but they have been observed as far as 200 miles from shore.

The tornadoes of the Guinea lands are not to be confused with the storms of the same name in the U.S.A. The latter have less rain, and far more violent winds revolving rapidly with a short radius.

Nigeria

This large and important dependency merits special description. Long series of meteorological observations are not numerous except from the coast.

Three belts may be distinguished. The north, including the country north of the central plateau region about lat. 11° N., is the driest and sunniest (mean annual sunshine at Kano 3,000 hours), and has clearly marked monsoonal seasons comparable with those of the Plains of India. December, January, and February is the cool season, but the mean temperature is as high as 70° in January. It never rains. The almost constant wind is the harmattan, and since the desert is not far distant it is very dry and dusty, so that clear air and bright blue skies are rare. Plants shed their leaves, and have various other devices to check loss of water.

In March temperature rises fast, and April, May, and early

June is the hot season. The sun is overhead, and in May, as few clouds have yet appeared to screen it, the heat is intense, the mean temperature exceeding 90°. But the wind is still NE. and the air is dry; night brings some relief from the excessive heat of the day, so that the weather is not unhealthy. June brings a sudden change; SW. winds set in with much cloud, and the rains begin. Tornadoes mark the change of season. Temperature falls under the cloud canopy, and the range from day to night is less than in the previous months. The air is almost saturated with vapour, and rain is frequent. Just as in the cool season Saharan conditions were in evidence, so now the weather is that of the Guinea coast. The rivers, many of which had dried up, roll along in heavy flood and much of Bornu becomes a great lake. The north gets least rain, but even the north frontier has about 20 inches, and the Kano district about 30 inches. The rains last till September; then temperature rises again as the sky clears, and this is the most unhealthy period, worse than the rains, but the rise in temperature is soon checked by the retreat of the sun to the south hemisphere. By December NE. winds are well established, and Europeans find life less burdensome.

The central belt comprises the country between the north and an arbitrary line about 7° N. Rainfall is abundant, 40 inches in the north to 60 in the south. Differences of altitude have considerable influence; the valleys of the Niger and Benue, only a few hundred feet above the sea, have less rain but higher temperatures than the uplands, and are heavily forested in parts and unhealthy. The Bauchi plateau, reaching 5,000 feet above sea-level, is much cooler and, though not high enough to have a temperate climate, is healthy and pleasant for Europeans during most of the year; the mean annual rainfall is about 40 inches. The rains last longer than in the north, at Bauchi from May to September, at Lokoja from April to October, and the temperature is lower in the rains and higher in the dry season.

The third belt includes the rest of Nigeria. Its main features are very heavy rainfall, the rains lasting nearly the whole year, and a small range of temperature. Most of it is low-lying, the Niger delta forming a large part, and here is the 'West

Coast' climate in its worst form. The usual tropical mangrove swamp fringes the coast and the brackish creeks and streams, the trees growing out of fetid black ooze which reeks with rotting vegetation. The climate is among the most unhealthy, with enervating moist heat day and night throughout the year. The winds are SW., the harmattan reaching the coast only intermittently in January and February. The temperature never falls below 60° at night, and is usually between 70° and 90° throughout the 24 hours. The sultry heat tends to weaken the strongest European constitution and leave it a prey to malaria and other diseases fostered by the climate and the insanitary native villages. Thunderstorms are frequent, on about 75 days a year. The mean annual rainfall exceeds 120 inches on the coast of the delta, and decreases northward to about 80 inches at Abo and 50 inches at Asaba; the higher land on both sides of the Niger has more than the valley-bottom. June and September or October have most rain; the break in August facilitates the harvesting of the early crops and the sowing of the later. March, April, and December are the hottest months, August the coolest, so that the usual seasons of the north hemisphere are reversed owing to the dense cloud-screen of the summer months, but the annual range is only about 5°. Lagos has 2,000 hours of sunshine a year (66 per cent. of that at Kano), and Tiko, on the very rainy coast of British Cameroons, only 1,390 hours. At Calabar the mean monthly cloud ranges from 7 tenths in the least rainy months to 9 in August.

CHAPTER VII

THE SUDAN EAST OF LAKE CHAD. EGYPT

Egypt

Long series of records are few in most of this region. The Nile valley, however, extending through 33° of latitude, is well equipped with meteorological stations, and provides a particularly instructive climatic 'section' from equator to Mediterranean. Moreover the climatic belts, which are clearly marked in West Africa, are continued eastward across the continent in similar latitudes, modified by topography.

The north coast has a Mediterranean climate of a very arid type, mild winters with some, but not much, cloud and rain, and hot rainless summers (p. 43); the mean precipitation is 8 inches at Alexandria, only 3 inches at Port Said. Snow falls very occasionally in winter depressions, but rarely lies for more than an hour or two; the mountains of Sinai, however, may be snow-capped for days. Thunderstorms are not unknown in autumn and winter in both Lower and Upper Egypt,

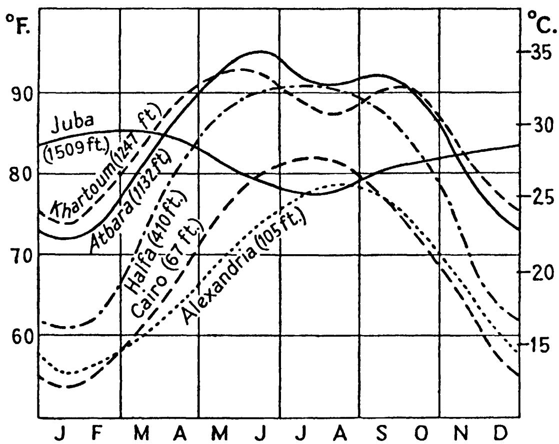


FIG. 20. Mean temperatures in the Nile valley.

and hailstones of over a pound in weight have fallen in the delta. Only a narrow coastal strip has this modified Mediterranean climate; at Cairo we reach a desert land with a mean rainfall of only 1 inch, all of it in winter. Even in the Delta the rain is too scanty and unreliable for agriculture without irrigation from the Nile; a small reservoir has been made in the east above El Arish to catch the rain-water which sometimes sweeps down the wadi, and it provides for some local irrigation.

Winter is cooler at Cairo than on the coast despite the lower latitude, but summer is much hotter (Fig. 20); the January mean is 54°, about the same as in the south of England in May. The air is dry; the mean relative humidity at Helwan in May is only 41 per cent., but it increases in summer, rising to its monthly maximum, 58 per cent., in September; the weather feels even sultry when the floor of the valley is inundated by the Nile flood and the air is calm.

Visitations by both hot and cold winds associated with pressure-irregularities are prominent in the winter half-year as in all the Mediterranean region. The hot winds, of an intensified scirocco type, are called Khamsin. They consist of tropical air from far south, from Arabia, the Gulf of Aden, possibly even the Arabian Sea, which travels north under the influence of an extension of the low-pressure system of the Sudan towards the north-east, a frequent development in spring. If now a shallow depression forms over the north of the Sahara, perhaps at the discontinuity between hot dry Saharan and cool damp Mediterranean air, and approaches Lower Egypt, the tropical air is drawn into it as an E. or SE. wind, very hot (temperatures up to 118° have been recorded at Cairo), extremely dry, and so hazy with fine dust that vehicles carry lights at midday. This is the khamsin, which may continue for 2 or 3 days. When the cold front of the depression from the west passes the weather changes abruptly; a cold blustering NW. wind sweeps down in the cold front raising dust and sand, the sky is clouded and sometimes showers fall. Most khamsin winds are of only moderate velocity, but some reach gale force. The mean frequency is about 3 a month in February, March, and April. Khamsins can give much hotter days (and nights) than are ever experienced in high summer, for in summer the fresh N. wind reduces the temperature; but the spells of excessive khamsin heat last only for a few days.

The cold winds are floods of polar air which sweep down from Anatolia or the east of Europe in rear of winter depressions. At such times fires are particularly welcome in the homes of Europeans in Lower Egypt, and the cold may be very perceptible even south of Khartoum. On 20 April 1929 such a polar current kept the maximum temperature at Cairo down to 63°, 21° below the mean daily maximum for the month, and was the cause of showers in Egypt, and of haboobs in the Sudan on the following day. Lower temperatures are known on calm nights in much of Egypt, the readings in the screen falling occasionally to 25°, and on the ground much lower so that water freezes, but this type of cold is restricted to the night, and temperature rises fast after sunrise.

South of Cairo we are in the true Saharan climate with its

monotonously cloudless sky and blazing sunshine. Steady rain is certainly rare; the mean total is negligible, for many years pass without a drop, but then, after perhaps 10 or even 20 years, a sudden downpour may give 1 or 2 inches in 24 hours; Siwa, Lower Egypt, had 1·5 inches on 28–29 December 1930, and the houses in the oasis suffered much damage. Temperatures are very extreme; Wadi Halfa has had 127° (in April, the highest record in the Nile valley) and 28°. The days are hottest farther south, the mean daily maximum in June being 111° at Merowe, but here the minima also are higher, 53° being the mean daily minimum in January. The mean daily minima are lowest in the north, at El Sheikh Fadl between Cairo and Asyut. Beyond this the warmth of the Mediterranean prevents a further fall; the January mean is 3° higher at Alexandria than at Asyut. Frost may occur in all the Nile valley between 20° N. and the middle of the Delta; it is more severe in the open desert, a minimum of 25° having been recorded at Dakhla (altitude 400 feet) and 26° at Siwa (−75 feet).

The lowlands of the Sinai Peninsula resemble Lower Egypt, but the mountains rise above 8,000 feet and have a mountain climate; above 4,000 feet the precipitation is heavy, falling sometimes in torrential downpours with thunder in front of winter depressions, followed by snow as the cold front passes. Khamsins are a feature of spring.

Temperature data for representative stations in Egypt and the Sudan are:

		Coolest month				*Warmest month*				
	Alt.		*Mean daily*				*Mean daily*			*Absolute*
	Feet	*Month*	*max.*	*min.*	*range*	*Month*	*max.*	*min.*	*range*	*extremes*
Alexandria	105	Jan.	66	51	15	Aug.	87	74	13	111, 37
Cairo .	67	,,	66	45	21	July	96	71	25	118, 25
Asyut .	182	,,	68	43	25	,,	99	73	26	121, 32
Siwa . .	−75	,,	68	39	29	,,	101	69	32	120, 26
Wadi Halfa	410	,,	75	46	29	,,	106	74	32	127, 28
Khartoum .	1,247	,,	90	59	31	May	107	77	30	118, 41
Kassala .	1,640	,,	93	61	32	,,	106	77	29	117, 43
Port Sudan	18	Feb.	81	67	14	Aug.	105	84	21	117, 50
El Obeid .	1,866	Jan.	87	53	34	May	102	72	30	115, 31
Malakal .	1,280	Aug.	88	71	17	Apr.	101	74	27	110, 52
Juba .	1,509	July	88	68	20	Feb.	100	71	29	111, 56

The Sudan

In the Nile valley south of Cairo the winds are northerly all the year, following the course of the valley almost exactly, and so strong and constant that the dahabiahs easily journey upstream under sail and return with the current. But a change begins about Berber, which has a short spell of southerlies and variables in July and August; they are the fringe of the monsoon of the Sudan, the west of which has been traced in the Guinea lands (p. 51). The transition from Sahara to Sudan is rapid, for Khartoum, only 160 miles south of Berber, has S. and SW. winds from June to September, giving 6 inches of rain, and dry north-easterlies for 8 months (Fig. 21); the climate is much like that of Timbuktu but drier. Representative wind frequencies are:

Wind Directions, Mean Percentage Frequencies
(Means of day)

	N.	*NE.*	*E.*	*SE.*	*S.*	*SW.*	*W.*	*NW.*	*Calm*
Alexandria									
Jan. . .	13	10	7	7	7	14	18	18	6
July . .	29	6	1	0	0	0	11	52	1
Cairo									
Jan. . .	13	5	1	5	26	14	8	3	24
July . .	34	5	1	1	0	1	20	21	17
Wadi Halfa									
Jan. . .	32	13	0	0	0	0	0	9	45
July . .	17	6	0	0	1	4	5	21	46
Khartoum									
Jan. . .	56	20	1	0	0	0	0	13	10
July . .	2	0	1	3	31	36	9	2	15
Hillet Doleib									
Jan. . .	68	23	1	0	2	0	0	0	5
July . .	1	6	11	11	34	9	3	1	23
Mongalla									
Jan. . .	31	15	20	4	8	3	5	9	5
July . .	9	6	13	14	25	7	7	3	15

The middle of the Sahara has almost cloudless skies throughout the year, but at Khartoum the effect of the monsoon on the sunshine is already prominent:

Mean Sunshine, Hours a day, at Khartoum

Jan.	10·6	Apr.	10·8	July	8·9	Oct.	10·4
Feb.	10·8	May	10·1	Aug.	8·9	Nov.	10·9
Mar.	10·7	June	10·0	Sept.	9·7	Dec.	10·7

South of Khartoum the skies are cloudier, the rains heavier and of longer duration, lasting from April to October at Lake No, and two maxima appear in the curve, to become more pronounced southward till at Rhino Camp, 3° N., the climate is equatorial, with rain most of the year, maxima in April and August (Fig. 21).

Summer is a very hot season in the Sudan, the heat being almost Saharan till the monsoonal cloud screens the sun and the rain cools the air, making a depression in the curve of

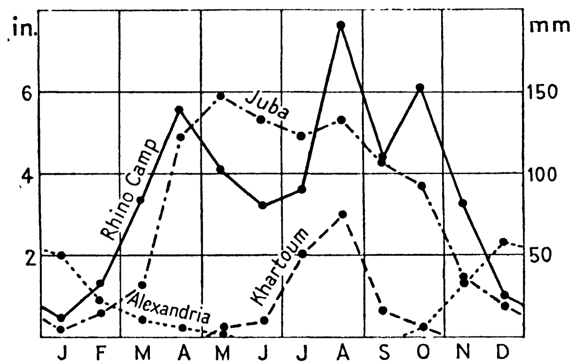


Fig. 21. Mean monthly rainfall in the Nile valley.

temperature amounting to only a few degrees in the north of the Sudan but becoming the minimum of the year in the south (Juba, Fig. 20). Thus in all its elements the dry tropical climate of the Sudan passes into the equatorial type about 5° S.

The change from desert to Sudan is less obvious to the traveller up the Nile valley since the Nile forms a continuous oasis. The date palm is cultivated from the Mediterranean coast to Khartoum, but the fruit is best between Cairo and Aswan, luscious dates which can be easily dried for export; to the north the air is rather too damp, to the south too hot and dry. South of Khartoum the date palm disappears and the land of the baobab begins.

Haboobs

The north of the Anglo-Egyptian Sudan has very severe dust-storms, 'haboobs', most of them in summer. Towering

pillars of dust rise like a wall to a height of several thousand feet along an almost sharp front about 15 miles long, which advances at about 35 miles an hour. Their immediate cause is a strong squall of wind blowing over loose dry dust; the squall is associated with abnormal instability between the moist SW. monsoon on the surface and the dry NE. harmattan above. There may be thunder, but the rain often evaporates before it can reach the ground. Haboobs are most frequent in the neighbourhoods of Tokar, Kassala, and Khartoum, where a deep covering of fine silt provides the dust (Farquharson, J. S., *Q.J.R. Met. Soc.*, 1937, July).

CHAPTER VIII

ETHIOPIA (ABYSSINIA). ERITREA. SOMALILAND

THIS region has great diversity owing to its extent in latitude (from the equator to 18° N.), in longitude, and in altitude. Four main regions are:

1. The highlands, a plateau block, the main mass of Abyssinia, altitude about 9,000 feet but rising to 15,000 feet in isolated peaks. A little snow falls in winter but none lies throughout the year; most of the precipitation falls as heavy rain in summer. The sides rise very steeply and on the west and south-west are intricately dissected by long river valleys and gorges, in places 2,000–3,000 feet deep.

2. North-east of the plateau is the Danakil (Afar) lowland, below sea-level in the north, rising in the south to about 2,000 feet, bounded on the west and south by the remarkably straight wall of the plateau, and on the east by the Red Sea hills of Eritrea. It is an arid tract, intensely hot and dry in summer, and the streams that enter it from the plateau fail to reach the sea.

3. In the south-east the plateau is cut by the Rift valley with its precipitous sides, drained by the Awash River, and the block on the south-east of the valley slopes comparatively gently through Ogaden and neighbouring plains to merge in the coastal belt of Italian Somaliland. The lower slopes are

very poor grazing land with scanty and uncertain rainfall of 10–20 inches, and a mean temperature at 4,500 feet about 60° in January, 75° in July. Most of British Somaliland on the north-east is highland of 3,000–6,000 feet, with a very steep drop to the Gulf of Aden.

4. The shores of the Red Sea and the Gulf of Aden, a very narrow strip, quite arid, with a mean rainfall less than 5 inches falling in winter. The coast of the Red Sea is backed by narrow highland over 4,000 feet, except where the Danakil depression reaches the sea about 15° N. The overhead sun, shining from cloudless skies and the additional heating of the air by descent after its passage over the sun-baked plateau behind, give excessive heat in summer; at Berbera the mean exceeds 90° in June, July, August, and September, and in July rises to 97° with mean daily maximum 107°, and mean daily minimum 88°—remarkably high figures, especially for a coastal station. January, the coolest month, has a mean of 76° (mean daily maximum 85°, minimum 68°). Aden, on the opposite shore of the gulf, with onshore winds, is 9° cooler in July, and in winter about the same as Berbera (table on p. 50).

Three main altitude zones are distinguished in Abyssinia:

1. Kolla, up to 6,000 feet, consists largely of valley-bottoms which share the hot summers of the Sudan; May and October are the hottest months. The valleys are sheltered from the general winds, and are damp, sultry, and unhealthy; they have much forest and dense jungle, and are quite unsuitable for white settlement.

2. Voina Dega ('wine highland'), 6,000–8,000 feet, is the most populous zone, with much well-cultivated land and excellent pastures. The warmest month is March, mean temperature 60–64°, and the coolest July, 55–57°, so that the temperature invites permanent European colonists. The volcanic soil is fertile, and irrigation could be provided for the dry months; disadvantages are the torrential rains in summer, and the steep slopes of the much-dissected land.

3. Dega ('highland'), over 8,000 feet. Cereals are grown up to 12,000 feet, but the higher altitudes are too cold and the rainfall too heavy to attract settlers.

Winds

Between October or November and March the NE. monsoon sweeps the whole region except the Red Sea south of Massawa which has S. winds. The monsoon is very dry by origin, rainless except for scanty precipitation on the higher windward slopes. In February or March low pressures develop in the east of the Sudan and attract the SE. trade of the Indian Ocean; the 'little rains' occur at its meeting with the NE. monsoon which is still in force north of 15° N. In June south-westerlies set in over Somaliland; they belong to the summer monsoon of south Asia, but here blow parallel to the coast (like the NE. monsoon) and give little rain; they continue till November, when the NE. monsoon replaces them. In Abyssinia also the general winds in June to September are SW. (much modified locally by the strong relief of the land), but they have crossed Africa from the S. Atlantic; in spite of their long land passage they give Abyssinia the very copious rains of its rainy season. The Red Sea has NNW. winds in summer in all its length. In the Gulf of Aden winds are usually light or moderate in winter; the SW. monsoon of summer is strong, often of gale force (when it is called kharif on the Somali coast, to which it descends sand-laden and with furnace-heat).

Rainfall

An all-important aspect of the climate of Abyssinia is the rainfall in relation to the Nile flood, since the summer rains are the chief source of irrigation of the Sudan and Egypt. Unfortunately, the meteorological records are disproportionate to their economic importance.

Most rain falls on the south-west and west of the plateau, including the upper valleys of the Sobat, Blue Nile, and Atbara, and exceeds 75 inches over a considerable area and 40 inches on most of the plateau above 6,000 feet; in the north it decreases to 20 inches. It decreases very fast on the north-east, which perhaps explains in part the straight, undissected plateau edge overlooking the arid Danakil depression, which is in striking contrast to the much-dissected south-west and west. The heights over 8,000 feet south-east of the Rift valley and south-west of Harar, with totals exceeding 60 inches,

share the good summer rains of the main plateau. From them the total decreases south-eastward to less than 10 inches in the lowlands, which share the aridity of the north of Kenya, and like it are scantily populated by poor pastoralists; but the coast south of 6° N. is more favoured (Mogadishu, 19 inches, nearly all in the months April to November). The perennial rivers Webi-Shebeli and Juba head in the rainy highlands, and have sufficient volume to give hope of large-scale irrigation schemes.

In the south of the plateau appreciable rain begins in February or March, and continues fairly heavy for a few weeks (the light rains); Addis Ababa has about 3 inches in March and in April; after a lighter spell in May the heavy rains begin, and last till the end of September, being specially heavy in July, August, and September. The rain is of the tropical mountain type, very heavy with much thunder. The water runs off rapidly into the deep gorges which are almost empty in winter, and the thick chocolate-coloured flood reaches the Nile valley in June and increases in volume till September, so copious that after irrigating the Sudan and Egypt some water is left over to enter the Mediterranean 1,700 miles away. On the northern plateau, including the Takkaze basin, the rains begin seriously in mid-April and continue throughout the summer, but much less heavily than in the south. The lower slopes of Ogaden have lighter rain, most of it probably in April, May, and June; but Harar (6,500 feet) has good rains from March to September. Winter is dry.

Except on the shores of the Red Sea and the Gulf of Aden where most of the very scanty rain (Massawa 7 inches, Berbera 2 inches) falls in winter, summer being cloudless and rainless, and in the Danakil region which has very little rain in winter and summer alike, the rains are restricted to the summer half-year, the effect of the plateau being to lengthen the rainy season somewhat and especially to increase the amount, the Nile valley having only 30 inches and the neighbouring plateau 75 inches.

Temperature

Temperature differs widely in north-east Africa with differences of elevation and topography and of cloud and rain.

In winter the coasts of Eritrea and French Somaliland are the hottest tracts owing to the heat of the water of the Red Sea; the January mean is 79° at Massawa, where the lowest temperature on record is 66°; Djbuti has similar figures. Thus even in midwinter these coasts have equatorial heat. Inland, with rapidly increasing altitude, the winters are cooler (Harar, 6,000 feet, January mean 66°), and are too cold for European settlement in the highest parts of Abyssinia; the air temperature not infrequently falls below 32° at Addis Ababa. Temperature rises rapidly when the sun enters the north hemisphere, and spring has the highest temperatures of the year, the thick clouds and rain of high summer causing a pronounced cooling (Addis Ababa, April mean, 62°, July, 58°; Harar, April, 69°, July, 66°); at some stations with heavy summer rains July and August have the lowest means of the year. But the rainless and almost cloudless districts, including the coasts of the Red Sea and the Gulf of Aden and much of Italian Somaliland, get hotter till July; Massawa has a July mean of 95° and has recorded 112°; at Berbera the corresponding figures are 97° and 117°. This coast has the highest annual mean, about 86°, of the globe, and only the fairly low humidity makes it habitable in summer. Summer is much cooler on the Indian Ocean shores of Italian Somaliland, thanks to the cool water off the coast (July mean at Mogadishu, 79°). The range from summer to winter is low on the plateau, 6° at Addis Ababa, 4° at Harar, but considerably more on the coasts, 21° at Berbera, 16° at Massawa, owing to the excessive heat of summer.

An interesting effect of these hot summers is found on comparing the temperatures on the plateau with those of the Red Sea coast and the Nile valley in summer and winter. The plateau is a little cooler relatively to the Nile valley (which also is cooled by the summer monsoon) in winter than in summer, and very much cooler in summer than in winter relatively to the arid lowlands on the east:

DIFFERENCE IN MEAN TEMPERATURE

	January	*July*
Hillet Doleib–Addis Ababa	23	22
Berbera–Addis Ababa	18	39

Visibility

Visibility is often only moderate in most of this region. In the dry season the air tends to be hazy with fine dust, and sand-storms add coarser particles. Smoke from grass- and bush-fires is a further source of haze in many districts. The Gulf of Aden and its shores are usually hazy in summer. The highlands of Abyssinia are often cloud-covered in the rainy season, but have good visibility in the dry. The shores of Italian Somaliland, and still more the adjacent Indian Ocean, have much fog in summer over the cool sea-water, fog being recorded in more than 40 per cent. of observations at sea from June to August for 200 miles south of Cape Guardafui.

CHAPTER IX

CAMEROONS. FRENCH EQUATORIAL AFRICA

The middle of this large region extends 1,200 miles east from south Nigeria into the heart of Africa. From its north, where it reaches Lake Chad, to its south extremity is 1,300 miles. Much of the central area, including British and the north of French Cameroons, is highland over 3,000 feet, small parts attaining 6,000 feet and the commanding peak of Cameroon Mountain 13,350 feet. South of this the narrow coastal plain rises to an extensive plateau of about 2,000 feet which falls gradually in the east to the Congo at 1,000 feet.

The climate is in general equatorial, with monotonous heat (absolute extremes at Duala 95° and 65°) and humidity, but there are large modifications. The far north of the region (Fort Lamy, p. 136) is in the Sudan and shares the climate and weather, including tornadoes, of the north of Nigeria. The highlands enjoy the usual alleviation of temperature by altitude which is well known in East Africa, but the favoured area over 5,000 feet which is best suited for white settlers is small, and the settlers are still very few; most of it is in British Cameroons, and in addition to its good volcanic soil it has the advantage over the highlands of Kenya of a much heavier, in places perhaps too heavy, rainfall. Most of French

Cameroons is considerably lower, but has many French settlers who live permanently on their plantations.

The rainfall has features of interest. The west of Cameroon Mountain has one of the outstanding totals of the globe; the annual means exceed 80 inches all round the Bight of Biafra, but rise far above 100 inches on the seaward side of the mountain; Debundja near sea-level has the extraordinary total of 374 inches (577 inches in 1919), and the higher slopes probably much more, but long series of observations are lacking. The rainfall is heaviest in July, August, and September, when the monsoonal indraft of humid equatorial air is steadiest and strongest. The driest, but by no means rainless, months are December, January, and February when the harmattan often reaches the coast with its dry, dusty air. Over the year about two-thirds of the rain falls in the night, between 1800 and 0600, the excess at night being largest in the driest months.

The 'hyetal equator', separating the rain régimes of the two hemispheres, crosses the region about lat. 3° N. where the régime is of a well-marked equatorial type; at Libreville, 0·5° N., the rains last from September till May with maxima in November and March, and June, July, and August are almost rainless, a south hemisphere régime. South of the hyetal equator not only does the régime of the rainfall change but the amount near the coast decreases rapidly from about 80 to only 40 inches in the south of Gabon, and the variability becomes larger (see p. 82). This is the beginning of the long dry west coast of Africa south of the mouth of the Congo.

CHAPTER X

THE BELGIAN CONGO

(For place-names see Fig. 23)

Physical Features

The core of the territory is a flat basin at an altitude of about 1,000 feet, drained by the River Congo and the middle and lower courses of its tributaries, and clothed with very dense rain-forest except where cultivation has intruded. The basin rises on all sides to the great African plateau, most of it

between 1,500 and 3,000 feet in the Belgian Congo but higher in the south-east (Elisabethville, 4,000 feet), a tract of savanna of varying tree-density but remarkably uniform over vast expanses. The east rim of the basin is still higher, much of it 6,000 feet, parts 10,000 feet, and its highest point in the Ruwenzori Mountains 16,800 feet, but this whole area, though high, is small; its central feature is the west Rift valley, the floor of which is at about 5,000 feet round Lake Kivu and slopes northward to 2,000 feet (Lake Albert) and southward to 2,500 feet (Lake Tanganyika); the sides rise very steeply to the altitudes mentioned above. The east frontier of the territory lies along the valley except where an eastward projection encloses the highlands of Ruanda and Urundi. In the west the Congo cuts through the surrounding plateau, the Crystal Mountains, here about 2,000 feet, in rapids, and a narrow lowland extends on the west to the sea.

The equator crosses the north of the territory from Coquilhatville to Stanley Falls and Ruwenzori, bisecting the forested lowland basin, and the usual type of equatorial climate, modified by the altitude of 1,000 feet, prevails from the north frontier to about 5° S. Most of the rest of the country has a plateau type of tropical climate, and the mountains in the east rise to alpine zones.

Air-Masses

The region is in the equatorial trough of low pressure, and shares all the main air-masses described in Chapter III. In January maritime tropical (Atlantic) air forms a SW. airstream in the west and south as far east as about 18° E. The middle and east, the greater part of the Belgian Congo, has continental tropical air from the north, the south-east maritime tropical air from the Indian Ocean, bringing the vapour for its rains.

In July (and during most of the period April to October) the south-westerly winds from the Atlantic are much stronger under the influence of the summer low pressures of the Sahara, and advance right across the continent, covering the west and north of the Belgian Congo and supplying the summer rains. The rest of the territory, south of the line Port Francqui to Juba on the Nile, is filled with maritime tropical (Indian

Ocean) air. The continental air from the north, which is prominent in January, has disappeared.

The winds are generally light in the equatorial climate, and almost always fall calm at night. Violent squalls, however, up to 50 miles an hour occur in tornadoes which are most frequent in the periods March to May and September to November. In their characteristics and structure they are similar to the tornadoes of the Guinea lands (p. 62), and, like them, travel from an easterly point, appearing generally in the hottest hours of the day.

MAJOR CLIMATIC REGIONS (Fig. 23)

Equatorial Basin. This is the flat central basin, between the northern frontier (the rivers Ubangi–Bomu) and lat. 5° S. The mean annual temperature is about 78° and mean annual range only about 3°; the hottest months are March and April, the least hot July and August. The diurnal range, however, is large, about 20°; as is usual in the equatorial climate the days are not excessively hot (mean daily maximum not exceeding 90°, and absolute maximum being about 100°), much cooler than in the Sahara, but the nights are sultry, with minima about 66° and very rarely down to 60° (absolute minimum at Eala 59°). Such temperatures continue monotonously throughout the year.

The mean rainfall is about 80 inches a year on the outskirts, increasing to 100 inches in the middle of the equatorial basin; the area with these amounts is less than in the Amazon basin and the East Indies, the other great equatorial regions, owing mainly to the shelter of the surrounding plateau. The rainy seasons (Fig. 22) are—on the equator, September to November and March to June, the former having most rain; in the north March to November (with a break in the rains in June and July); in the south September to May (with rather less rain in December and January). The rains are associated with the intertropical front in its passage north and south, but vigorous local convection adds its effect, and the dry seasons get some, though much less, precipitation; the extreme north and south have 2 or 3 rainless months. According to the few relevant records most of the rain falls in the night and early morning, the proportion being largest in the rainy seasons; the

afternoon has a secondary maximum which is largest in the dry seasons. At Bambesa, 3·5° N., 66 per cent. of the annual total falls between 1700 and 0800, and the percentage rises to 81 in April and November.

The air is always moist, more moist than is usual in the latitude, owing to active evaporation from the great rivers, pools, and swamps, and transpiration from the massive vegeta-

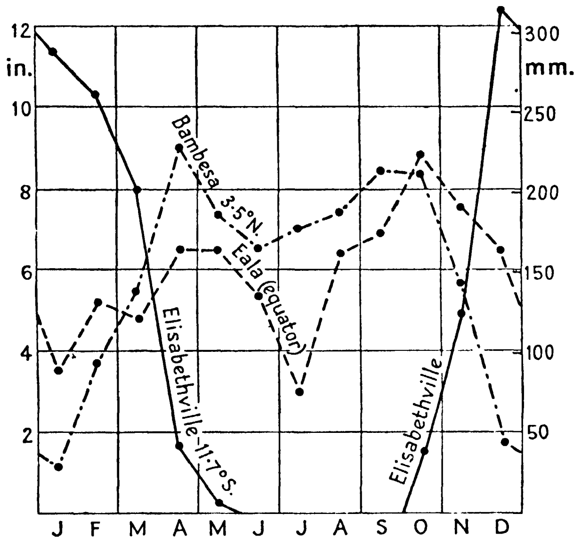


FIG. 22. Mean monthly rainfall.

tion of the rain-forest, and probably much of the rain is derived from this source. The cooling of the saturated air at night often forms a shallow fog, mostly in the dry seasons, but it is always dissipated by 1000.

The Southern Plateau includes the large expanses south of about 5° S. and has a tropical climate of the plateau variety, the tropical characteristics becoming more pronounced with increase of latitude and altitude. The annual range of temperature is notably larger than on the equator, the mean being 14° at Elisabethville, lat. 12° S. There the warmest season is spring, before the clouds and rain of summer reduce the temperature; the mean for October is 75°, for January only 71°. The coolest month is July with 61°, when ground-frost is

not unknown. The daily range is large, as is to be expected on a plateau, 20° in the rainy season, 37° in the dry—unusually large ranges even for a plateau (we may compare Kabete, Kenya, altitude 5,971 feet, which has 17° in the coolest month, 24° in the warmest, or Pretoria, altitude 4,350 feet, with 22° and 31°).

The mean annual rainfall, about 70 inches in the north,

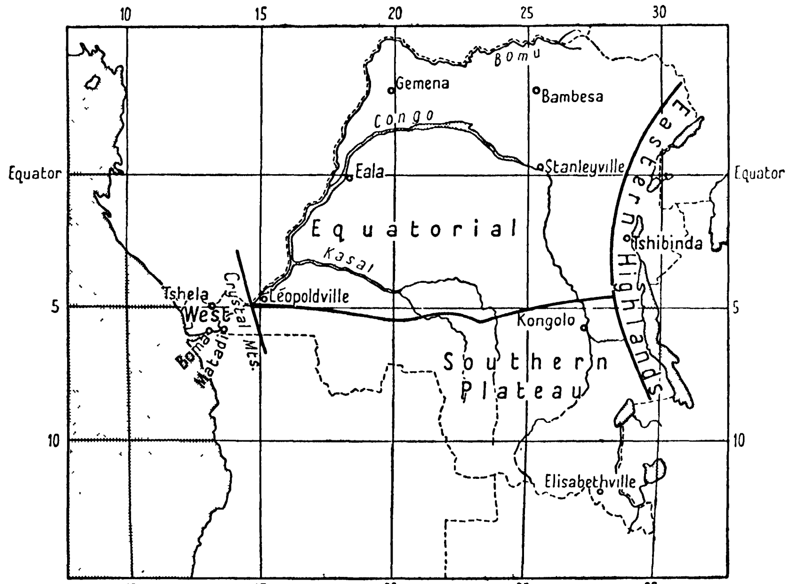


FIG. 23. Major climatic regions of the Belgian Congo.

decreases southward to less than 50 inches (45 inches at Elisabethville). The rains (Fig. 22) begin in November and continue till March (October till April in the north); the rest of the year is dry and almost rainless, with nearly cloudless skies, which, however, are often grey with smoke-haze from bush-fires towards the end of the season; Elisabethville has 2,678 hours of sunshine a year. In climate, as well as in vegetation and landscape, the country resembles the plateau of Northern Rhodesia, and though it is not ideal for Europeans the cool nights and the long cool dry season of brittle weather enable many to pass their lives in comfort.

The Eastern Highlands. The Rift highlands form the west of Uganda and Tanganyika Territory as well as the east of the Belgian Congo, and the climates are similar on the two sides of the frontier. The altitude lowers the temperature, so that even on the equator permanent residence is possible for Europeans, though not yet usual, between 6,000 and 8,000 feet, above which it is too cold; indeed, even at 6,000 feet, domestic fires are necessary, and the nights, and many of the days, are cheerless with damp chilly air and cloud-fog which blots out the landscape. The heights of Ruwenzori are snow-covered and have glaciers; they are nearly always hidden by cloud.

Rainfall is heavy, over 100 inches a year in places, except on lee slopes and in rain-shadows, but much of the floor of the Rift valley has little (the north of Lake Tanganyika less than 40 inches) and is a land of grass and poor savanna; parts, however, are forested, being abundantly watered by the streams from the highlands, the heavier rains of which are suggested by their very frequent cloud-cover which screens them from the observer on the surrounding plains.

The West. The lower altitude west of the Crystal Mountains tends to make the western area warmer than the interior, but this is counteracted by the constant SW. winds from the cool waters off the coast, which are strong in the afternoons from about 1300 till sunset under the influence of the sea-breeze; the mean annual temperature is about 78°, the same as in the interior, but the range is much larger, 8° on the coast and 10° some distance inland. March is the warmest month, mean temperature 82°; July the coolest, 72°.

The rainfall decreases rapidly on the coast towards the south-east, from 60 inches a year to less than 30 inches, an effect of the cool Benguela Current, which is largely responsible for the rainless coasts farther south, notably in South-west Africa. The rainfall on the coast is very variable as well as scanty; at Banana, in the years 1908–13 in which it was measured, the annual total ranged from 69 inches in 1908 to 8 inches in 1913, the mean being 44 inches; at Boma, annual mean 39 inches, it ranged from 54 inches in 1911 to 22 inches in 1918. The variability is due directly to the oceanic conditions; normally the Benguela Current with varying width and

volume washes the coast and the rainfall is small, but sometimes it is replaced by the hot Guinea Current advancing farther south than usual, and moist air, cloudy skies, and heavy rains result. The rainy seasons in this area are March–April and October–December; the major dry season is May–September.

Régime of the River Congo. The River Congo has a large seasonal variation of volume; below the confluence of the Kasai the level is controlled mainly by the southern tributaries fed by the rains of the south hemisphere; even at Léopoldville on the large expanse of Stanley Pool the mean highest level, in December, is about 11 feet above the mean minimum which is due in July and August; a minor maximum in May and minimum in March result from the smaller contribution of the north hemisphere streams. Above the Kasai confluence the north hemisphere influence predominates and gives the highest flood in October in the middle Congo. Above Kongolo the Lualaba (upper Congo) and its tributaries are flooded by the south hemisphere rains in January, February, and March.

CHAPTER XI

BRITISH EAST AFRICA (KENYA, TANGANYIKA, UGANDA)

(For place-names see Fig. 26)

THIS region lies astride the equator, in latitudes where climate tends to uniformity. But many variations, and those of much economic importance, result from the relief, which ranges from an equatorial coast, through highlands which have become the home of many European settlers, to snow-capped mountains, with vast open upland plains stretching boundless to the view and lakes which are inland seas. Most of Kenya and Uganda are equatorial, but Tanganyika Territory extends south to lat. 12° S., and in the south has the tropical climate of the south hemisphere.

In this chapter a description of the main climatic elements over the whole region is given first, and then the major climatic divisions are indicated, with their more prominent features.

Topography

The details are complicated but the major features simple. The coastal plain to an altitude of about 1,500 feet is more than 300 miles wide in the north, but only 50 near Mombasa; south of Tanga the coast diverges from the edge of the plateau, and leaves a large lowland triangle which contains some tracts of low upland.

The interior is essentially a plateau. In Kenya the land rises steadily westward to the edge of the east Rift valley at an elevation of about 9,000 feet, but in places more than 13,000 feet, above the sea; the plateau above about 4,500 feet forms the Highlands of Kenya. West of the Rift valley is a gentle slope to the basin of Uganda, which is about 4,000 feet above sea-level (Lake Victoria, 3,717 feet), and a rise again in the west to broken uplands, over 5,000 feet in much of Ankole overlooking the west Rift valley. The interior of Tanganyika Territory is more uniform, most of it being a vast plateau about 4,000 feet above the sea, with an elevated rim on the east, south (where it reaches 9,000 feet), and west.

The east and west Rift valleys are sunk 2,000 feet, in places much more, below the highlands, and in most of their length they get little rain; but they contain many lakes, some of which have considerable climatic influence; Lake Victoria, the largest lake of all (not in a rift valley), is a sea with its own maritime climate, and is the main source of the humid climate of the west and north-west of Uganda; Lake Kioga and the many swamps and sluggish rivers in the country within about 40 miles north of the lake add to the humidity.

Many elevations rise on the plateaux, some of them tabular, others isolated summits; the largest, Kilimanjaro (19,000 feet), Kenya (17,000 feet), Ruwenzori (17,000 feet), and Elgon (14,000 feet) are huge mountain masses, the first three snow-capped, with glaciers descending to about 15,000 feet. Mount Meru, west of Kilimanjaro, the Pare and Usambara Mountains on the south-east, and the Ulugurus rising like an island in the wide lowland west of Dar-es-Salaam, are other prominent elevations. All these heights stand out on the map of rainfall. The wide range of latitude, altitude, and surface gives great differences in all the climatic elements; notable

extremes are the west and north of Lake Victoria, warm, humid, and rainy; the semi-desert tracts of the north of Kenya with almost Saharan conditions; the snow-covered peaks. Uganda (except the north and north-east) is a green land of rich verdure all the year; the arid north of Kenya is always brown and dry, much of it bare rock or sand; the highlands of Kenya and Tanganyika are parched and brown most of the year, but soon put on a green covering with the onset of the rains in October and in February.

Pressure and Winds

In most regions the atmospheric pressure is of little climatic significance in itself, but in the highlands of East Africa the reduced pressure is regarded by some as an important physiological factor. At 5,000 feet the mean pressure is about 855 mb. (25 inches), at 7,000 ft. 795 mb. (23 inches). The difference from the sea-level pressure of 1050 mb. (30 inches) is hardly appreciable by most residents, but may possibly be deleterious in the long run to certain types of physique.

East Africa is dominated by the great pressure-systems of south Asia, the South Indian Ocean, and south Africa. In the northern summer south Asia is covered by the vast low-pressure system which extends west over the Sahara; in the sub-tropics of the South Indian Ocean and south Africa the sub-tropical high pressures are at their maximum. The SE. trade, of maritime tropical air, sweeps north, becoming the SW. monsoon after crossing the equator. In the northern winter Asia has very high pressures, south Africa low, the equatorial trough extending east from it over the Indian Ocean in about lat. 10° S. in January. The NE. monsoon brings continental polar air from Asia; it backs to NW. south of the equator.

These alternating winds from south and north blow with great constancy parallel to the coasts of East Africa, the former from May to September as a moderate to strong SE. wind as far as the equator and SW. beyond, and the latter from November to March as a NE. wind rarely exceeding a velocity of 20 miles an hour and never reaching gale force. In the transition months, April and October, the winds are light and variable, but usually from an easterly point. On the main

currents the land- and sea-breezes, always prominent in low latitudes, are superposed, with the result that the winds in the day are SE. or NE., in the night SW. or NW.

The SE. trade is a steady current, but even it is subject to irregularities, 'surges', many of which come from the westerlies of the Southern Ocean to enter the trade east of Mauritius and travel with it into East Africa and often far beyond. The surges are linear disturbances with squally winds, much cloud, and some rain. They are prominent on the ocean and also in East Africa, where the cloud and rain are intensified by orographic and convectional ascent, and locally by the vapour from lakes and swamps.

Two other air-masses appear in East Africa at irregular intervals, the northerly current of the north and interior of the continent (shown in Fig. 8) in the months November to March; and more frequently a westerly current, often in the higher levels between 10,000 and 12,000 feet, important in causing general rains.

Up-country the winds are less regular both in direction and velocity than on the ocean or the coasts. The topography has a large local effect in low latitudes both at night and in the day, and may modify the usually light general winds almost to the point of reversal. In East Africa other factors also are important. At an altitude of over 5,000 feet the plateau is above the surface-winds of the ocean, and to some extent shares the upper winds of their elevation, much modified. The lakes, notably Lake Victoria, like seas, develop their own land- and sea-breezes very prominently and regularly. Another feature is the formation of a stable layer of cold air on the surface at night, calm except near steeply sloping ground where katabatic winds may be strong (as in the Rift valley). The calm nights are in marked contrast to the days when the wind blows freshly, sometimes over 20 miles an hour for long spells; these strong breezes help to reduce the physiological temperature.

The table of mean wind frequencies below illustrates the points mentioned. To show the strong diurnal control the frequencies are given for the first observing hour in the morning and for the afternoon; the difference is prominent on the shores of the ocean and the great lakes.

WIND DIRECTIONS, MEAN PERCENTAGE FREQUENCIES

January	*Alt. feet*	*N.*	*NE.*	*E.*	*SE.*	*S.*	*SW.*	*W.*	*NW.*	*Calm*
Kabete, 0900	5,971	15	58	16	1	0	0	2	1	7
1500		4	53	39	3	0	0	1	0	0
Equator, 0900	9,050	3	87	6	0	0	2	0	1	1
(long. 35·5°E.) 1500		4	50	31	3	1	2	3	5	1
Entebbe, 0830	3,878	20	6	5	3	8	7	20	22	9
1430		2	1	15	30	39	6	6	1	0
Dar-es-Salaam, 0900	30	51	24	2	0	1	3	2	1	16
1500		36	56	5	0	1	0	0	0	1
Tabora, 0830	4,151	5	14	28	25	13	5	3	4	3
1430		7	16	18	13	11	9	11	9	5
Lindi, 0900	131	11	2	1	9	21	18	2	21	15
1500		8	72	2	1	1	3	1	6	7
Mogadishu, mean of 0800, 1400, 1900	39	3	72	13	9	0	0	0	3	0
July										
Kabete, 0900	5,971	2	4	11	26	24	10	2	0	21
1500		2	9	29	42	11	5	2	0	0
Equator, 0900	9,050	8	44	4	2	2	13	15	7	5
1500		5	24	15	2	4	18	22	6	4
Entebbe, 0830	3,878	25	7	3	6	6	6	15	28	4
1430		1	1	7	39	34	12	2	2	2
Dar-es-Salaam, 0900	30	0	0	0	3	24	62	1	0	10
1500		0	2	5	55	31	7	0	0	0
Tabora, 0830	4,151	0	11	62	26	1	0	0	0	0
1430		1	2	20	47	26	3	0	0	1
Lindi, 0900	131	0	0	0	0	25	74	1	0	1
1500		6	49	8	22	6	6	0	1	2
Mogadishu, mean of 0800, 1400, 1900	39	0	0	1	5	7	81	6	0	0

THE SEASONS; RAINFALL

The seasons may best be treated in terms of the humidity and rainfall which are their main features in the tropics. A first distinction is between the equatorial zone as far south as about 3° S. (5° S. on the coast) and the inner tropical zone of the south hemisphere to which the rest of the region belongs; the extreme north of the region is in the inner tropics of the north hemisphere, but its area is too small for detailed description here. The régimes at some representative stations are illustrated in Fig. 24.

The equatorial zone has four well-marked seasons:

(*a*) The hot season, January and February, is the driest as well as the warmest season, and has the reputation of inducing irritability in white settlers up-country. It has less cloud than the rest of the year, but the mean exceeds 5 tenths in the highlands; there is most cloud in the afternoon, when it forms

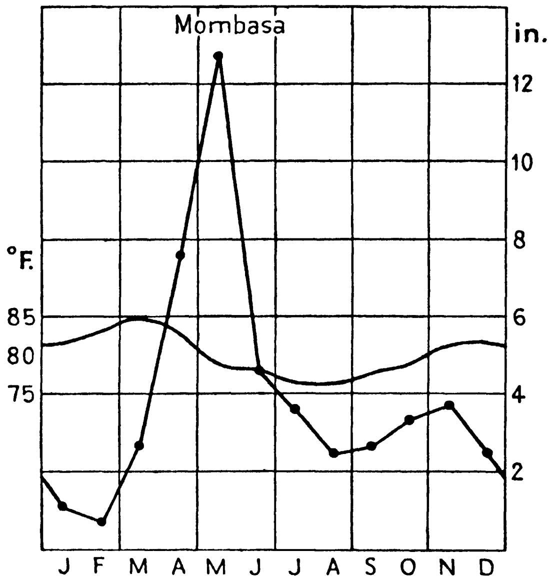


FIG. 24*a*. Mean monthly temperature and rainfall, Mombasa.

a useful screen against the powerful sunshine. At Kabete the mean relative humidity falls to about 42 per cent. at 1430. The rain is not enough for plant-growth, but heavy instability showers, some with thunder, are frequent in the afternoons on the higher ground. At elevations below 6,000 feet the afternoons are hot, with temperatures rising to about 80°, but temperature falls rapidly after sundown and the nights are cool, with minima about 55°. The coast gets little rain; the days are hot and oppressive, but the sea-breeze sets in about 1000 and the cool ocean air is a welcome alleviation.

(*b*) The 'long rains', March to May; about half the mean rainfall of the year is in these 3 months. The cloud and rain make the days cooler than in the preceding months, but the

nights are damp and sultry. At the approach of the rains vegetation shoots up and the land becomes green; the rivers flood and the earth roads are almost impassable. The year's

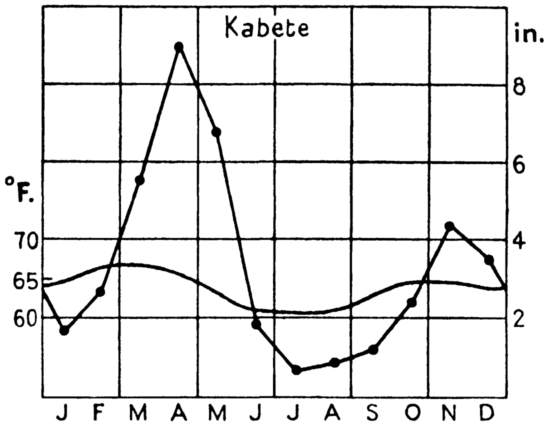


FIG. 24*b*. Mean monthly temperature and rainfall, Kabete.

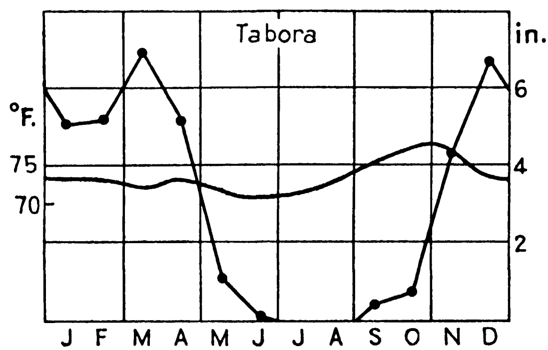


FIG. 24*c*. Mean monthly temperature and rainfall, Tabora.

agriculture is largely dependent on good rains in this season. On the coast the weather is notably humid and sultry, with occasional thunder, but the mean temperature is rather lower than in January and February.

(*c*) The cool season, or winter as it is appropriately called, June to October, gives only a small amount of rain in the highlands, but the number of rain-days is considerable. On the

coast, too, it is a relatively dry period, with 2 or 3 inches of rain a month, most of it in short but heavy showers. This is distinctly the coolest season, and on the coast much the most pleasant for Europeans since in the rest of the year the equatorial heat and humidity are enervating, though the fresh sea-breezes make them less oppressive than in many parts of the tropics. Up-country in the Highlands the season well merits its local name 'winter'. On a typical day in the early morning we find the sky overcast with thick low stratus cloud, not infrequently giving a steady unpleasant drizzle (which may continue till noon under the influence of frontal disturbances). The air is chilly and cheerless, cold above 6,000 feet, indeed too cold above 10,000 feet for European settlement (frost may occur above 8,000 feet). About 1000 the cloud usually begins to break and the sun appears; it gets warm, and almost hot in the bright sunshine of the afternoon; the sky is about half covered with white cumulus clouds, and a fresh breeze blows. Towards sunset temperature falls fast, cloud begins to overspread the sky, and the night is so cold that fires are welcome. Except in the most settled weather there is a risk of convection-showers, sometimes with heavy thunder, in the late afternoon, particularly on the high ground, both isolated summits and the escarpments above 7,000 feet.

Early in September the weather improves and becomes noticeably warmer; the morning cloud is less extensive, and the overhead sun is hot most afternoons. There is less drizzle, but rain, now mainly convectional rain in the late afternoon, may be considerable. Temperature rises on the coast also.

(*d*) The 'short rains', mid-October to December, give about half the rainfall of the long rains. Temperature remains high, and in most years the season is not unpleasant despite the rain. But on the coastal lowlands the rising temperature and humidity, and the rain, are irksome for Europeans.

The equatorial régime of rainfall, and the associated seasons, are common to all Uganda and Kenya except the extreme north which has the tropical régime of the north hemisphere. Tanganyika Territory, south of about 3° S. in the interior and 5° S. on the coast, has the south hemisphere régime with one rainy season and one long dry season; in the interior the rains begin in October or November and continue till April,

being heaviest in January and February generally. Most of the rain falls in heavy showers, often with thunder, on about half the days; cloud is considerable, and humidity high, very noticeably so at night. It is a damp, sultry, season and much of the land is waterlogged. The wind is light from the east (except in some violent thunder-squalls) in the daytime, but falls calm at night. The dry season, May to October, with its brittle weather, is a great contrast. The wind blows fresh from E. or SE.; with little cloud and no rain at all the sun shines powerfully, and the air is dry. It is hot in the middle of the day, but the nights are pleasantly cool, much cooler than during the rains. The land soon dries out, herbaceous vegetation withers and most trees lose their leaves.

The amount of rainfall (Fig. 25) is only moderate to poor for the latitude, and for this some general reasons may be suggested: the main wind-systems are parallel to the coasts and not onshore; the SE. trade is dried by heavy condensation on the mountains of Madagascar which it crosses before reaching East Africa, and the NE. monsoon has little moisture after its long land passage; the equatorial trough in which most of the rain falls passes the region rapidly, being hastened far to the north in the northern summer and far to the south in the southern summer.

The rainfall is least in north Kenya, where large areas have less than 10 inches, and north-east Uganda, and from this dry tract in the east of Kenya, much of it useless desert very thinly peopled, a wide tongue of forbidding thorn-bush with less than 20 inches protrudes south, almost reaching Tanganyika Territory between Kilimanjaro and the sea, and an arid tendency continues far to the south-west. The middle of Tanganyika has only 30 inches and is poor steppe, many parts being dry brown sand most of the year, but improving to low savanna in the better-watered areas; it has few inhabitants and but small possibilities of agriculture in the absence of facilities for irrigation. The east Rift valley is in a rain-shadow, with less than 10 inches in the north round Lake Rudolf, and less than 20 inches in the south (Magadi 15 inches); the west Rift valley is better watered both by rain (about 40 inches a year) and rivers, but has less rain than the bounding

escarpments and mountains where the totals rise to over 80 inches.

Of the more favoured areas the coast south of Lamu has about 40 inches, the off-lying islands much more. Most of Uganda has 40 to 50 inches, parts of the north and north-west shores of Lake Victoria more than 70; this is the rainiest tract of East Africa, and also the most densely peopled and among the most prosperous; it owes its advantage to the prevailing winds from the lake, and is very different from the south-east shores. But not far away is the tract of Ankole with comparatively poor rainfall (less than 40 inches), much of it uninhabited grassland, running north from Tanganyika into Uganda between the lake and the west frontier. The other good rainfalls are on mountain-slopes facing the prevailing winds; such are the Usambara and Uluguru Mountains near the sea in Tanganyika with over 60 inches. Even in the arid wastes of the north of Kenya the mountains near Marsabit are a green oasis with over 30 inches; the giants, Mounts Kenya, Kilimanjaro, Ruwenzori, and Elgon, have over 70 inches, much of it snow on the summits which are nearly always cloud-covered.

The Tana and Pangani, fed by Mounts Kenya and Kilimanjaro, are perennial and useful rivers; the former is of such volume in its lower course that the possibility of a large-scale irrigation scheme has been favourably considered. The escarpments and adjoining highlands overlooking the Rift valleys have enough rain for evergreen forests, and feed the sources of many streams. The highlands north-east of Lake Victoria, including the Mau and Nandi escarpments and much of Kavirondo, also have large totals—and many thunderstorms; they hold a dense native population, and the middle altitudes have many white settlers. The uplands on the north of Lake Nyasa stand out prominently on the map with over 100 inches.

The highlands of Kenya, containing most of the European settlements, average 40 to 50 inches a year, the amount increasing with altitude. The mean is scanty, and if the rains are at all deficient crops suffer, for even the mean is insufficient for an equatorial land of high altitude and strong insolation, where evaporation is vigorous and the best, volcanic, soils

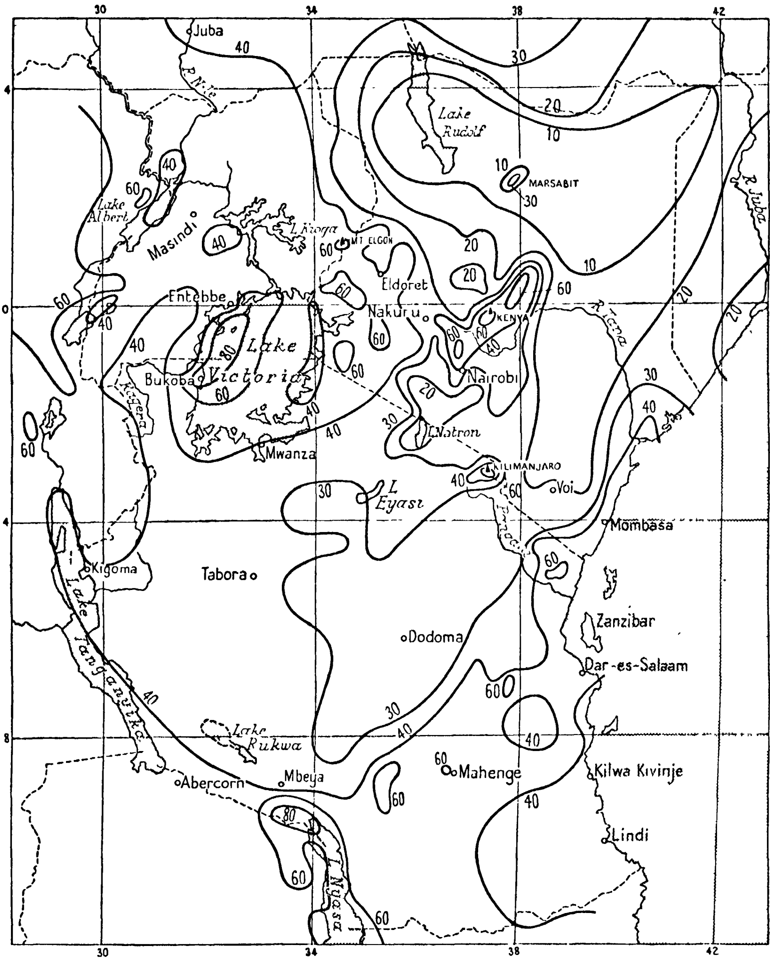


FIG. 25. Mean annual precipitation
(based on records of East African Meteorological Department).

very permeable. In spite of the not very favourable rainfall the population, both black and white, is relatively dense.

The mean rainfall, then, of East Africa as a whole is by no means abundant, and an additional disadvantage is its uncertainty. A whole 'rainy season' may pass with little or no rain, and serious deficiencies for periods of two years or more, resulting in widespread agricultural failures, are not unknown.

Uganda is fortunate in that the rainfall is less variable as well as more abundant than in the other dependencies, and her agriculture less precarious:

ANNUAL RAINFALL (in.)

	Mean	*Highest record*	*Lowest record*
Entebbe	59·2	89·1	39·3
Fort Portal	57·2	77·2	42·0
Nairobi	34·3	61·8	19·1
Tabora	35·1	51·3	15·4
Dar-es-Salaam	43·7	53·5	17·2

Three types of rain are common. In all seasons, both on the coast and up-country, heavy instability showers, many with thunder, are conspicuous. On the plateau most are in the late afternoon and evening, few after midnight. Violent squalls up to 50 miles an hour may introduce the storm; a gust of 91 miles an hour has been recorded at Kisumu. Hailstorms are not infrequent in the west of Uganda. Lake Victoria is interesting in getting almost all its abundant rain, most of it in heavy instability showers, during the night and early morning, the day being cloudless except for middle and high cloud; the night storms, often of great intensity, drift north and west over the shores between Jinja and Bukoba. Another interesting variation is on the ocean coast, where most of the convection-showers, often very heavy, are in the early morning, few in the afternoon. The second type, steady frontal rain, may fall everywhere, and last with little intermission for several hours or even more than a day.

The third type, drizzle, is especially a feature of winter on the plateau above 2,000 or 3,000 feet, and is well known in the Nairobi district. It falls from low stratus cloud, and in its more persistent forms is frontal. It occurs in the night and early morning, never in the afternoon. Probably much of the vapour condensed was carried up by convection in the previous afternoon.

The rainy seasons of the equatorial zone are at, or just after, the transitions between the NE. and SE. trades, and appear to be due mainly to convergence in the intertropical front; the convergence is more prominent in the upper than in the surface winds. Other convergences that give much rain are of the monsoons (both NE. and SW.) with the westerly winds, and of the latter with the northerly air-mass from north Africa

(p. 86). Probably most of the rain is frontal, reinforced, however, by vigorous convection.

TEMPERATURE

The coast has the usual equatorial monotony, with a high but not excessive monthly mean about 80° and a small mean annual range. The mean daily maximum is about 90° in the hottest months, 82° in the coolest, and the corresponding minima are 77° and 68°. The highest record at Mombasa in 14 years was 96°, the lowest 66°, at Dar-es-Salaam 94° and 59°; the high minima suggest the still and sultry nights with vapour-laden air which are a feature of equatorial climates. But, thanks to the fresh ocean-breezes of the daytime, this coast is less enervating for white residents than most equatorial coasts, and the cooler months, July to September (May to November south of Dar-es-Salaam), form a pleasant season.

The plateau is cooler according to altitude; at Kabete, 5,971 feet, the monthly means range from 67° in February to 60° in July; the highest record is 87°, the lowest 41°. Thus the mean temperature is that of an English July, but the annual range is only 7°, as little as on the coast, and the conditions seem at first to be monotonously uniform. However, even this small difference is felt more than might be expected, partly because the human body loses its resilience to temperature changes in a monotonous climate and tends to become more sensitive, and partly owing to the more abundant and powerful sunshine in the warm months, which heats objects exposed to it but without a corresponding rise in air temperature. The insolation is stronger with increasing altitude, the more so in the clear air of the plateau; but the duration is much reduced by cloud. Physiologically the contrast between the hot, dry season and winter is very noticeable.

The diurnal range is large, the mean at Kabete rising from 17° in winter to 24° in February. It is larger in the dry areas; at Nakuru in the east Rift valley July has the lowest, 24°, February the highest, 35°. This large and rapid change from day to night is an important feature of the Highlands physiologically; on a sunny afternoon light tropical clothing is ample, but before sunset it already feels cool, and by dusk European clothes are desirable.

Uganda, thanks to its lower altitude, is warmer than the Highlands, and has a smaller range of temperature owing mainly to the more humid atmosphere. It is distinguished by the absence of a cold, or even cool, season, rather than by a notably hot warm season, and by its warm nights, much warmer than in the Highlands of Kenya. The monthly means are about 72°, and the mean annual range is even less than on the coast, being under 3° on the shores of Lake Victoria, 6° in the drier north. The diurnal range at Entebbe increases from only 12° in May to 16° in January, at Gulu in the north from 17° in July to 27° in January. Climatically Uganda is a favoured land, pleasant and by no means unhealthy for white residents provided they take long leave every three years or more often. It is equatorial in many respects, including its small range of temperature, its bright sunshine and cheerful skies, its damp atmosphere, its good and well-distributed rainfall which nourishes the luxuriant vegetation, green all the year; but its altitude raises it above the uncomfortable heat and humidity which make equatorial lowlands unsuitable for Europeans.

The plateau of Tanganyika is considerably warmer (except in its dry season) than Uganda, and has a larger range of temperature, both annual and diurnal.

The relation between temperature and rainfall at representative stations is shown in Fig. 24.

Sunshine and Cloud

In the following tables Dar-es-Salaam and Zanzibar illustrate the coast, Tabora the plateau, Kabete the Highlands in the medium altitudes of European settlement, and Kampala and Entebbe Uganda.

Mean Cloud (tenths of sky covered)

	J.	*F.*	*M.*	*A.*	*M.*	*J.*	*J.*	*A.*	*S.*	*O.*	*N.*	*D.*	*Year*
Dar-es-Salaam, 0830	7	7	6	6	6	5	5	5	5	6	6	6	6
1430	6	6	7	8	7	6	7	6	5	5	5	5	6
Kabete, 0830	5	6	7	9	9	9	8	9	8	8	9	7	8
1430	5	6	7	7	7	8	8	8	7	7	7	6	7
Tabora, 0830	7	7	7	7	5	3	2	3	4	5	6	7	5
1430	7	7	8	7	7	5	4	4	5	7	7	7	6
Entebbe, 0830	7	8	8	9	9	8	7	7	7	8	8	7	8
1430	6	7	7	7	7	7	7	7	7	7	7	7	7

MEAN DURATION OF SUNSHINE (hours)

	J.	*F.*	*M.*	*A.*	*M.*	*J.*	*J.*	*A.*	*S.*	*O.*	*N.*	*D.*	*Year*
Zanzibar	251	243	213	*180*	210	220	235	253	254	**270**	250	259	2.838
Kabete	**291**	245	261	229	172	145	116	*114*	156	202	212	255	1,956
Tabora	*216*	218	219	227	283	303	310	297	**312**	301	240	217	3,143
Kampala	**238**	193	189	195	187	189	*139*	168	157	172	178	205	2,210

The coast has abundant sunshine; an interesting feature is the greater amount of morning than of afternoon cloud in many months; the tendency to early-morning rain has been mentioned already. The sunny afternoons, the cooling breezes from the ocean, the bright skies with dazzling scattered heaps of cumulus cloud, are a memory which old residents cherish.

The plateau of Tanganyika has almost unbroken sunshine in the days of the dry season, with hardly a cloud in the morning and only a little light cumulus in the afternoon. The rainy season is much more cloudy, especially in the afternoons, but even the rainy season has far more sunshine than the south of England.

The Highlands of Kenya are less favoured. December to March is a period of good sunshine, without excessive cloud. But in April the long rains are at their height, and in June the cloudy skies of winter begin, when the sky is overcast with heavy stratus on most mornings, and the afternoons have much cumulus; the sun is powerful when it does shine, but the sunshine record for July and August is below the average of the south of England.

Uganda, in sunshine as in altitude, is midway between the Highlands of Kenya and the coast. Entebbe, like the rest of the north and west of the lake, has most cloud as well as most rain in the mornings, but in the Protectorate generally the afternoons are cloudiest, with towering cumulus building up for showers.

VISIBILITY

East Africa has good visibility. The air is notably clear in the rainy seasons, when it is not unusual to be able to see Mount Kenya, distant 80 miles, and Kilimanjaro, 130 miles, from Nairobi. In the dry seasons visibility is reduced by dust-haze, sometimes increasing to thick dust in dust-storms, by smoke from bush-fires, and by more or less intense shimmering every sunny afternoon. These last factors are less prominent in the damper climate of Uganda.

Fog is very rare at low altitudes, and infrequent on the Highlands below 7,500 feet; above that level cloud is liable to be down to the surface. In Uganda shallow mist is common at night on the marshy banks of the many sluggish rivers, but it always dissolves by 0900; similar mist, at times increasing to thick fog, may form at night in low wet hollows everywhere during the rains. Representative data for the coast and the Highlands of Kenya are:

Percentage of Observations with Good or Very Good Visibility (range 10 km. or more)

Mombasa,	Feb.,[1] 0830	95	Kabete,	Feb.,[1] 0830	99
	1430	100		1430	100
	May,[2] 0830	81		Aug.,[2] 0830	90
	1430	85		1430	98

[1] Month with best visibility. [2] Month with worst visibility.

Climatic Regions

Fig. 26 shows the major climatic regions, based on the broad features and necessarily ignoring the many local details (some of them important) imposed by the topography. The climatic elements have already been described.

1. Coastal, equatorial (but with poor rainfall in the north).
2. Coastal, tropical (south hemisphere régime).
3. Lowland, interior (south hemisphere régime).
4. The arid north of Kenya and north-east of Uganda, low in the east, but rising to over 8,000 feet in parts of the west. Little rain, especially round Lake Rudolf. Very thin population, mostly pastoral nomads.
5. The eastern Highlands of Kenya; may be subdivided at Makindu into the east section, lower, warmer, and drier, and the west, cooler, with much cloud and moderate rainfall; the latter has rich volcanic soil, and not only carries a large native population but is also the main area of white settlement and farming.
6. The western Highlands beyond the Rift valley, similar to the west of 5, but with more cloud and rain (in one long rainy season, March to September, not two as in 5).
7. The rainy belt north and west of Lake Victoria; very good agricultural land with a dense native population.
8. North and west Uganda.
9. The mountainous south-west of Uganda and north-west

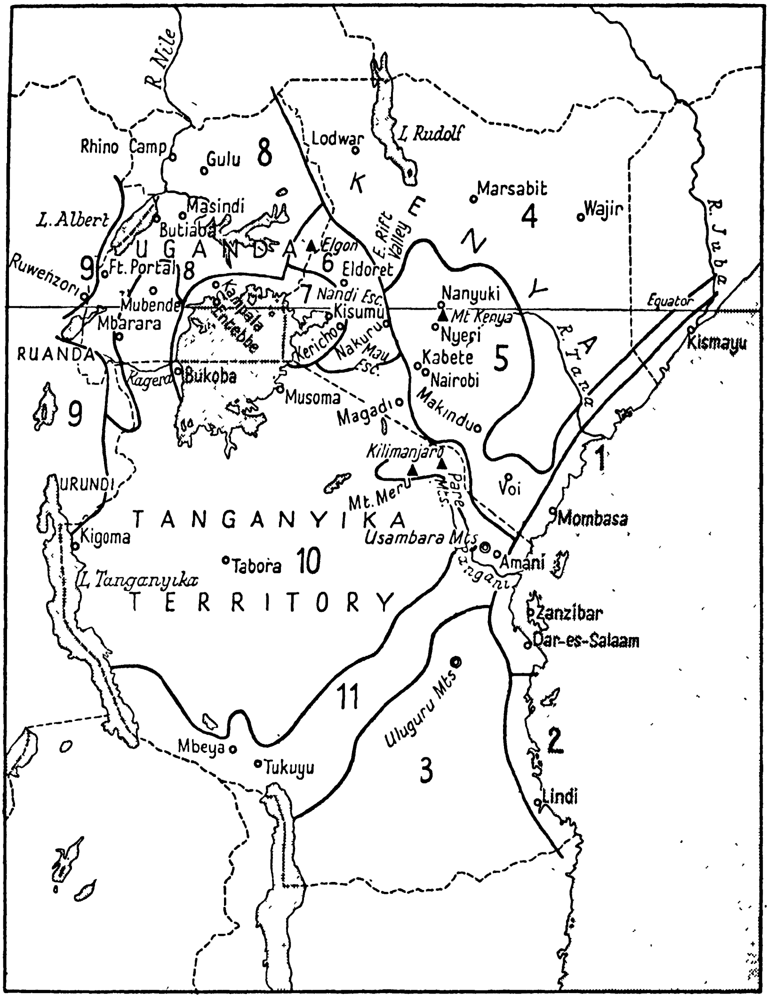


FIG. 26. Major climatic regions of East Africa.

of Tanganyika, with good rain, about 50 inches, distributed over much of the year; the middle altitudes have a large native population.

10. The plateau of Tanganyika; poor and unreliable rainfall; most of the east is a land of steppe and open bush-savanna, thinly populated.

11. The elevated rim on the east and south of 10; has more

rain, especially on Kilimanjaro and Meru in the north, and the Tukuyu highlands in the south which offer good prospects for settlement when communications are opened up.

White Settlement in East Africa

The Highlands of Kenya Colony and Tanganyika Territory are the only area of any extent in the equatorial zone of Africa high enough to provide a 'temperate' climate. Some of the features of significance for the health and comfort of white residents have already been mentioned. The atmospheric pressure is appreciably lower than at sea-level, the average being about 800 mb. (23 inches). The reduced pressure may be of some direct physiological importance; it certainly has the indirect effect of making the insolation stronger when the sky is clear than at sea-level; there is, however, a good deal of cloud during much of the year. This effect of altitude is important on mountains even in middle latitudes, and the insolation at 6,000 feet on the equator may be powerful enough to be not only uncomfortable but injurious. The glare of the sunshine as well as its high actinic power are certainly unpleasant after a time, and in the opinion of some observers their effect, especially on the nervous system, is such that few white men can wisely spend their whole lives in the Highlands, and colonization in the usual sense will never be practicable since the new generations will necessarily deteriorate. It is commonly held that long residence on the Highlands tends to produce a highly-strung nervous condition which is most noticeable in the warmest and driest months.

Another drawback for white settlement is the monotony of the mean temperature. The monthly mean is rather higher than the July mean in the south of England, with little change from month to month—a pleasant and healthy temperature; but north Europeans are adapted to variability, to both a seasonal rhythm and to irregular weather-changes, and it seems doubtful if they can flourish permanently in this monotonous warmth. However, too much stress can be laid on the monotony of the monthly means, for there are redeeming features—a large range from day to night, as described on page 95, which goes some way to replace the large seasonal range of higher altitudes, and the cloudiness. Cloud is an

effective screen against the sun, and the difference between days with much and days with little cloud is significant; a damp cloudy day in the Highlands in winter feels distinctly cold, but a day with bright sunny skies is warm or hot. The months with most sunshine are much warmer physiologically relatively to the cloudy months than the mean air temperatures indicate.

While many are agreed that white settlement is possible in the restricted sense that the settlers can pass the prime of life in the colony but should take long leaves in Europe, and others are enthusiastic believers in the possibility of real permanent colonization, most claim that white men cannot engage in ordinary manual labour. But this is by no means certain. Up to the present no fully satisfactory tests have been made; some evidence suggests that daily physical work would be not only possible but beneficial for whites above 5,000 feet, at any rate if the warmest months, January and February, are excepted.

Uganda has only small areas in the south-west and on the slopes of Elgon at an elevation to correspond with the Highlands of Kenya, and almost the whole country is essentially a black man's land. Tanganyika Territory has many white settlers in the north, on the volcanic soils round Mounts Kilimanjaro and Meru at an altitude of about 6,000 feet, where the climate resembles that of the Highlands of Kenya, but most of the plateau is neither high enough nor well enough watered to be attractive. The Tukuyu district, a large area of highland north of Lake Nyasa, seems to be very suitable if it were opened up by road and rail. It is high enough to have a suitable temperature and a good rainfall, and being 8° of latitude from the equator it has a considerable range of temperature.

CHAPTER XII

ANGOLA

ANGOLA is a transition region between the rainy Congo and arid South-west Africa. The main divisions are the coastal lowlands, generally about 60 miles wide. and the interior

plateau which rises steeply, to altitudes of 7,000 feet in the highlands of Benguela, and descends more gently in the east to under 4,000 feet.

LITTORAL

The dominant controls of the arid climate of the coastal lowlands are the cool Benguela Current, and the SE. trade-wind which is constant at sea, but on the coast itself is deflected to blow from SW. and S. all the year, the westerly component being a sea-breeze effect; at night the land-breeze usually gives light N. winds. The rainfall is scanty, the annual mean decreasing from 20 inches in the north to less than 2 inches in the south; it is very variable—Luanda has had as much as 34 inches and as little as 3 inches in a year in a period of 41 years. The Benguela Current is responsible for the poor rainfall; it is notably foggy and the W. winds bring cool damp air and much fog from over it in winter, but little measurable rain. The fog and very low stratus cloud (which sometimes gives drizzle) are similar to those of South-west Africa (p. 109); cacimbo is the local name. They may spread inland to the west of the plateau, and are valuable in preventing extreme drought, but more of the scanty precipitation is contributed by occasional convection-showers in summer. Poor scrub covers the north of the littoral but the south is desert. The littoral is rather cool for the latitude, particularly in summer, the mean temperature of the warmest month being 80° (March) at Luanda, 77° at Lobito, and only 71° (January) at Mossamedes. South of Lobito it is cool enough for Europeans to maintain their normal habits in food, clothing, and dwellings. The following passage describes the climate of the new port of Lobito:

It is comfortable throughout the year, largely owing to the open position on the peninsula. Almost every morning about 10 o'clock the wind sets in from SW., cool and refreshing after its passage over the Benguela Current; the warmest time of the day is just before this sea-breeze sets in. In the dry season, May to October, the temperature is always pleasant (during my stay in August it never rose above 70° or fell below 63°), and the sea-breeze and frequent sea-fog prevent excessive drought, the relative humidity at midday rising to over 70%. Cacimbo is very frequent in July and August, spreading landward over the coastal plateau as far

as the west of the Bocoio Plateau, where it rises to about 2,500 ft.; if the fog is not dissipated by 10 or 11 o'clock when the sea-breeze begins, it usually continues all day; the sky is overcast and the wind so chilly that warm European clothing is welcome; visibility may be reduced to 200 yards or less in the morning, and about 8 or 9 o'clock a fine drizzle begins to fall.

The last weeks of the dry season are free from fog, the days, and still more the nights, become warmer, and cumulus clouds appear in the east in the afternoons.

In the rainy season, November to April, the rain falls in a few heavy thunderstorms which always come from north. The usual annual total is only 8 to 12 inches, but the amount is very variable; in the rainy season of 1932/3 it was 32 inches, and one day in February had 4·1 inches, another 4·4 inches, and another 8·9 inches in a few hours. Temperature is high, especially in April, but not sultry as it is at Luanda. At times the air is so damp that water drips from everything.

Leave every 3 years is enough for Central Europeans. Malaria occurs, but is not nearly so prevalent as in the neighbouring districts.

Plateau

The plateau above 4,000 feet has much more rain than the coast, enough for agriculture; the annual mean is over 40 inches, and exceeds 60 inches in the high west-central area; Villa Bandeira has 42 inches. The rainy season is summer, October to May, with an appreciable break in the rains in December and January. Most of the rain falls in thundery showers coming from the east; the weather is damp and, except at high altitudes, sultry; the warmest months are October and January. The cool and dry season is May to September, when the daily range of temperature is fairly large, the nights being distinctly cool or even cold, owing to the rapid loss of heat through the clear atmosphere. Frost is frequent in the south, and not unknown in the north, of the plateau.

The plateau resembles the highlands of East Africa and Northern Rhodesia in its possibilities for white settlement, but the area at a suitable altitude is much smaller.

CHAPTER XIII
PORTUGUESE EAST AFRICA (MOZAMBIQUE)

TOPOGRAPHY

THIS is an extensive territory, 1,250 miles in length, almost all of it inside the tropic. The differences of climate between plateau and coastal plain and lowland are prominent as everywhere in east and south Africa; Mozambique has an unusually large proportion of lowland.

From the south frontier to the River Zambezi the land is low-lying and marshy except for low plateau at about 1,000 feet in Gazaland, and the east slopes of the Lebombo Mountains and the escarpment of Southern Rhodesia (much of which exceeds 6,000 feet, a small area 8,000) along which the frontier runs. The Zambezi valley is a large tongue of lowland between Southern Rhodesia and the south-east of Northern Rhodesia and south of Nyasaland; the floor of the valley is under 250 feet above the sea at Tete, and under 1,000 feet at Zumbo on the frontier 550 miles upstream, and most of it is flooded in the rainy season. North of the Zambezi the relief changes; the coastal plain is much narrower, and rises gently to the plateau which fills most of the interior, with altitude under 3,000 feet but exceeding 4,000 feet in the west where it overlooks Lake Nyasa.

PRESSURE AND WINDS

In winter, April to November, the equatorial trough of low pressure is far to the north, and the SE. trade dominates both the whole of Portuguese East Africa and the Mozambique Channel. In midsummer the intertropical front has returned to the south hemisphere and is over the tropic; the NE. monsoon follows it south as the prevailing, and fairly constant, wind as far as about 20° S.; between that latitude and the south of Mozambique the winds are variable, from all directions except west, but still originate largely in the SE. trade, but at times in the NE. monsoon when the front oscillates south. The NE. monsoon brings moist, sultry, equatorial air which provides most of the rain. Near the coast the general winds are masked

by the regular land- and sea-breezes; gales are few, but can be violent in tropical cyclones, which, however, are rare, and most of them recurve to the south-east in the Mozambique Channel before they can reach the coast.

Rainfall

Summer is the rainy season, with heavy rain of the usual tropical type, associated with convergence in the intertropical front and increased by vigorous convection of the hot moist air. Over half the mean annual total is in the 3 summer months and about 80 per cent. in the summer half-year; but winter is not quite rainless though distinctly a dry season. The largest rainfall, exceeding 60 inches in some areas, is on the Southern Rhodesian escarpment and the highest parts of the plateau between the Shiré River and the sea. The lowest is in the Zambezi valley above the Shiré confluence, less than 30 inches, and in the interior between the Limpopo and Sabi rivers, a region of poor, dry, tropical grass and thorn-bush with less than 15 inches. Elsewhere totals average about 45 inches in the north, 30 inches in the south.

Temperature

Temperature is high and fairly uniform, especially in summer, over the whole territory (allowance being made for altitude), an effect of the Mozambique Current from which the air comes moist as well as hot. In January the means range from over 81° in the north to 78° at Lourenço Marques; but a very hot and sultry area is the lower Zambezi valley from the moist unhealthy delta to some distance above the Shiré confluence with means exceeding 85°. The plateaux are cooler, but except on the highest levels the means are still about 75°; they have the great advantage of cool nights. In winter the means on the coast are about 72° in the north, 65° in the south, the mean annual range being 10° in the north, 13° in the south. On the plateaux the means at 2,000 feet are about 67° in the north, 65° in the south, and the nights are really cool, minima falling to 35°; above 3,000 feet frost occurs. But the range is not enough to compensate for the very sultry summers and make the climate of the lowlands comfortable, or even reasonably healthy, for Europeans except in the south.

CHAPTER XIV
MADAGASCAR

THE climate of this large island is tropical, hot and humid, with heavy summer rains, but much modified by the bold relief.

PRESSURE AND WINDS

In winter the whole island is in the maritime tropical air of the SE. trade (Fig. 9). Meeting the high and continuous escarpment which rises 50 miles from the east coast the wind is deflected to blow from NE. south of latitude 20° S., but it remains south-easterly in the north, sweeping with greatly increased velocity round the north of the island, and often reaching gale force in the afternoon round Diego Suarez. On the plateau the wind is light, and the plains in the west and south-west are so sheltered that the winds are mainly of local character.

In summer the equatorial trough is far south, with the intertropical front about 15° S.; south of it the SE. trade persists, but on the north are light variables, with north-westerlies in the north-west, being in part the deflected trade from beyond the equator but largely local on-shore winds drawn in to the heated land. The usual sea-breeze is prominent both on the east coast where it reinforces the trade, and on the west where the weakening of the trade leaves an open field for local influences; but the land-breeze at night is more prominent in the west than the east.

RAINFALL

Summer is the season of cloud, and of rain which falls in very heavy downpours, often in thunderstorms and sometimes in tropical cyclones. The east, with its high escarpment, has most, over 100 inches (123 inches at Tamatave), some of it in winter. The central plateau has a mean of 40 to 80 inches, with hardly any rain from April to October. In strong contrast the south-west and south are dry, even to semi-aridity, with means falling below 20 inches, and the summers are the hotter

under the less cloudy skies. The north-east of the island has good rains in summer, about 40 inches even at Diego Suarez in one of the driest districts, but none in the long dry winter. The north-west has a small area round Nossi Bé with excessive rains in summer from the NW. winds which meet the highland near the coast; Nossi Bé itself has 92 inches, part of it in

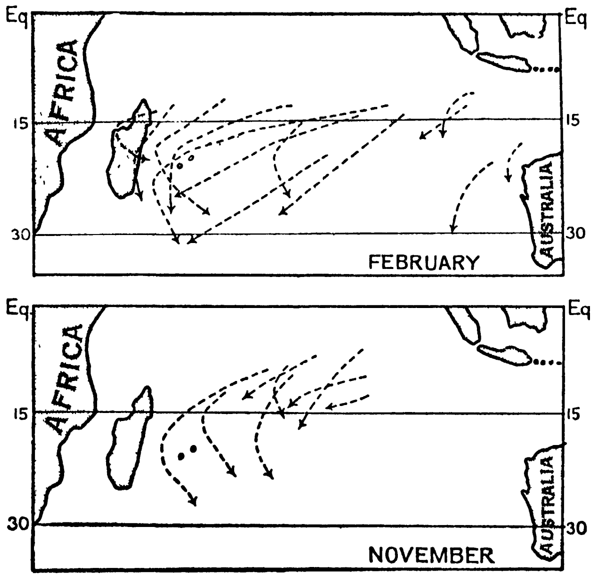


FIG. 27. Generalized tracks of tropical cyclones, South Indian Ocean.

winter. The west and north-west is one of the most thundery regions of the globe.

TEMPERATURE

In January (summer) all the western lowlands have means of 80° or 81°; the very cloudy and rainy east coast is cooler, but has means over 79°. Altitude reduces the means on the highest parts of the plateau to below 70° (Tananarive, altitude 4,530 feet, 70°).

In winter the differences are larger. The north-west is warmest, with July means over 75°, and the east coolest, under 65°, except the plateau which has under 60° (Tananarive 58°). In the south-west the means are about 65°. Thus the mean annual range rises from under 7° in the humid tropical north-

west to over 15° in the dry south-west; on the plateau it is about 12°.

Tropical Cyclones

These violent storms are a serious danger and work great havoc in the Indian Ocean, especially between lats. 8° and 25° S. and west of long. 70° E., which contains Madagascar, the Comoro Islands, the Mascarenes (Réunion, Mauritius, and Rodriguez), and many small groups (Fig. 27). Their season is December to April; round Mauritius 92 per cent. have occurred in those months, none in the period June to September:

Number of Cyclones in the Mauritius Region in 10 Years

Jan.	13	Apr.	6	July	0	Oct.	1
Feb.	17	May	2	Aug.	0	Nov.	2
Mar.	12	June	0	Sept.	0	Dec.	8
				Total	61		

Most originate on the warm ocean between 5° and 15° S., 60° and 90° E. and travel first south-west towards Madagascar; they rarely reach the Seychelles. Many follow a parabolic course, and the summit of the parabola shows a tendency to swing north and south with the sun, the cyclones commonly recurving about 22° S. in January and February, and sometimes as far north as 14° S. in May; most recurve between 18° and 22° S. Their track is often almost a semicircle round Réunion and Mauritius, which are then the scene of widespread devastation. After recurving the cyclones move away towards the south-east. But the tracks are very irregular.

CHAPTER XV

SOUTH-WEST AFRICA

From the mouth of the Congo a tendency to low rainfall shows itself in the west of the continent, and becomes more and more pronounced southward into South-west Africa. That territory, with the arid tracts of British Bechuanaland, is the counterpart of the Sahara, but is less arid owing chiefly to the less width of the southern land-mass; the Kalahari is poor bush rather than desert.

South-west Africa may be divided into three major regions, the coastal strip (the Namib), the highlands, and the Kalahari.

The coastal strip is less than 100 miles wide, and most of it less than 1,000 ft. above sea-level; in the east it rises steeply to the plateau. It is an almost waterless desert of rock and sand, with hardly any vegetation. The cool Benguela Current washes its shores. The dominant wind is the SE. trade, almost constant at sea, but masked on the coast by the alternations of land- and sea-breezes which are very prominent; almost daily it falls calm soon after sunset, and the land-breeze sets in as a light wind from a northerly point, to continue till morning. About 1000 the sea-breeze begins, the wind backing through W. to SSW. in the afternoon. Its force increases southward along the coast to reach a maximum between Lüderitz and the Orange River, where the velocity exceeds 30 miles an hour every afternoon for long spells; these strong winds raise the sand and drive it along—a trying feature of the climate; and the dust often greatly reduces visibility. A heavy south-westerly swell, from strong winds far out at sea, beats on the shores.

The cool waters off the coast are noted for fog and low cloud, and on most nights in winter this comes in over the land, generally as low stratus cloud, often with fine drizzle; the sky remains overcast till morning, clearing in the heat of the day; sometimes there is fog instead of cloud. Along most of the coast the winter half-year is the foggier, but south of Lüderitz most fog is in summer, and at Port Nolloth, south of the Orange River, the foggiest months are December to April. The annual mean at Port Nolloth, the foggiest station on this cold-water coast, is 85 days with fog; Walvis Bay has 55 days, and Luanda, at the north end of the fog-belt, only 25; in this, as in most other respects, the Namib is in striking contrast to the other side of south Africa, where Durban reports fog on the average only once in 2 years. On the nights of fog and drizzle the air is raw and damp and the ground is quite wet by morning; paradoxical though it seems in a country where agriculture is impossible owing to lack of rain, the fog, low cloud, and moist air are among the great discomforts of life.

But their contribution to the rain-gauge is small; a larger source is the convection-showers which, very occasionally, reach the coast from the interior. The mean annual rainfall is less than 1 inch, but back from the coast, away from the cool sea, the total may be estimated at perhaps 4 inches; the only perennial streams are the Cunene and the Orange; the other watercourses very rarely carry water to the ocean, but occasionally the rivers come down in high flood. North of Lüderitz summer is the season most liable to rain; south of that point begins the winter maximum of the south-west of the continent.

The mean temperature, and especially the daily maxima, are notably low in summer owing to the cooling of the westerly winds by the Benguela Current, and the annual range is small. The difference from the east of the continent in the same latitudes is again striking. But the weather is very variable from day to day; the unpleasant cool, damp, or foggy periods have been mentioned above; when the sky is clear, however, the sun is powerful (it is overhead in summer) and the heat soon becomes excessive if the wind is from the land, to be followed by a cold night. Another source of abnormal heat is the 'berg winds', strong easterly winds when the barometric gradient is steep between an anticyclone in the interior and low pressures over the ocean. They are most frequent in winter; they give clear skies, very low humidities, and remarkably high temperatures, the highest temperature of the year, up to 100°, sometimes being recorded in winter under their influence. The berg wind is interrupted by the sea-breeze in the afternoon, so that the highest temperature is in the morning. The heat seems to be due in part to the ordinary föhn effect of their descent from the plateau to sea-level, but probably other influences are equally important (p. 121).

The highlands of the interior are a very different land from the coast; the altitude of the central tract exceeds 6,000 feet. The mean temperature (Fig. 28) is slightly lower in winter, but much higher in summer, than on the coast, for the altitude is more than counter-balanced by distance from the Benguela Current and by the clear skies. The range of temperature, both annual and diurnal, is much larger on the plateau. There is little cloud, the air is clear and dry, and the sunshine powerful,

so that the summer days are very hot; but on winter nights frost is frequent; on one occasion a temperature of 109° in the afternoon was followed by frost at night at Windhoek. The rainfall is far heavier than on the coast; it is least in the south, but even at Windhoek the annual mean of 14 inches produces good pasture for stock-rearing; Grootfontein has 23 inches, and agriculture is possible without irrigation. In the north the highlands, with over 20 inches, have low forest. The rain falls in summer and autumn, from November to

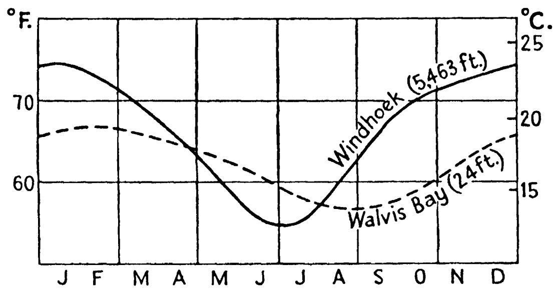


FIG. 28. Mean temperatures.

April, in the intertropical front, much of it in thunderstorms due to the instability of the air on the hot surface; winter is rainless with dry air and dry ground.

The third division of South-west Africa, the country east of the highlands, at an altitude of about 4,000 feet, is part of the Kalahari, a semi-desert of poor scrub, including the basin of the Molopo River, which, however, rarely contains running water. The rainfall is least, under 5 inches, in the south-west; in the north it rises to 30 inches. The rain falls in summer in scattered showers, very variable from year to year. As in other arid regions the range of temperature is large, the summers being very hot, the winters cool to cold.

CHAPTER XVI

NORTHERN RHODESIA. NYASALAND

NORTHERN RHODESIA

BY far the largest area is plateau clothed with savanna, ranging in altitude from over 6,000 feet in the north and east

to about 3,500 in the south; but the valleys of the Zambezi, Kafue, and Luangwa are below 3,000 feet. The distinction between highland and lowland climate holds here also, but unfortunately even the highlands of Northern Rhodesia, especially south of Lake Tanganyika, are not altogether free from malaria. The capital has now been moved, partly for reasons of health, from Livingstone, in summer an uncomfortably hot even if no longer unhealthy town on the Zambezi, to Lusaka, 300 miles north-east on the open plateau 4,000 feet above the sea.

The rains begin with thunderstorms towards the end of October and set in definitely in November, when the equatorial trough has swung south to cover south Africa. They continue till March when the intertropical front begins to retreat north. The mean annual rainfall is about 50 inches in the north, 30 inches in the south in the Zambezi valley.

Of the three well-marked seasons in the year, May to September is the dry season with E. and SE. winds, dominated by the sub-tropical high pressures, dry and rainless, cool and comfortable, the mean monthly temperature at the average altitude of the plateau being about 64°; the nights are always cool, and liable to ground-frost. The end of September, October, and early November is the hot season of overhead sun, with monthly means about 74°; the earlier weeks have dry brittle weather, but the later a good deal of cloud and some thunderstorms in the hot hours. December to March is the rainy season, with high humidity and heavy rain, much of it in thunderstorms, breaks in the rains and fine weather being the exception; the mean monthly temperature is about 70°, the drop from the hot season being due to the dense cloud and the cooling effect of the heavy rain. Except in the rains the climate is notably sunny. The winds remain easterly all the year.

Nyasaland

The distinction between lowland and highland is as important here as elsewhere in Africa. The lowlands, the valleys of the Zambezi below Zumbo, the Shiré, and their tributaries, and the shores of Lake Nyasa, have a tropical climate, malarial and unhealthy.

The heat is frightful just before the rains, the temperature occasionally being as high as 118° in the shade, though at night-time falling to 85°, thus rendering it possible to live. In the height of the rainy season the range of the thermometer is not so great, but the heat is often more unbearable owing to its greater uniformity and the moistness of the air. In the months of January, February, and March, the thermometer may be 100° in the daytime and only fall to 85° or 90° at night (SIR H. H. JOHNSTON).

The rainy season is very clearly defined, and comprises the months October to April. After a slight break at the end of December, when the sun is farthest south, the rains return with renewed vigour, and January and February are the wettest months. The annual mean in the Zambezi valley between Zumbo and the Shiré–Zambezi confluence is about 30 inches, and in the lower Shiré valley about 45 inches. It is larger towards the north up the Shiré valley, and the north-west shore of Lake Nyasa has probably between 60 and 80 inches. These lowlands are hotbeds of malaria and other tropical diseases.

The highlands, fortunately of considerable extent, present a great contrast, and life is not only possible but comfortable for white men, though malaria is not unknown:

Such a place as Zomba (3,000 feet above the sea) may be taken as a fair sample. During the cold season from May till September we have a day temperature not exceeding 75° and a night temperature ranging from 40° to 60°. In the months of September, October, and November, the temperature may rise to 98° and fall at night to 65°. During the height of the rainy season the day temperature ranges from 75° to 95° and the night from 65° to 70°.

At Blantyre, 3,000 feet above the sea, the mean annual temperature is only 68°; frost occurs occasionally at night in the dry season. The mean annual range is about 14°, and the mean daily range varies from about 24° in October to 13° in June. At these altitudes the heat is never oppressive, and still higher the climate is rather too cold for comfort. The humidity is considerable all the year. The rainy season is November to April as in the lowlands, but above 3,000 feet no month can be called rainless, and Mlanje (Mozambique) has almost 2 inches of rain even in July and August. The rainfall is far heavier than in the valleys; Lauderdale has as much as 108

inches, Zomba 55 inches, which may be regarded as a typical figure except in the highest and most exposed positions. But Blantyre has only 36 inches, being perhaps sheltered by the mountains on the north. The mountains round the north of Lake Nyasa are exceedingly rainy, with over 100 inches in parts. The lake is liable to south-easterly gales in the dry season, which are a danger to native canoes and even to lake steamers.

CHAPTER XVII

BRITISH SOUTH AFRICA (SOUTH OF THE RIVER ZAMBEZI)

(For place-names see Fig. 38)

DESPITE its great extent through 19° of latitude this region has so many features of topography and climate in common that it may be treated as a whole. Almost all the interior is plateau of considerable altitude, highest in the north, which falls very steeply to a narrow coastal plain. The plateau formation is a fundamental climatic control, and the main altitude divisions are of great climatic significance:

1. The coastal plain and adjacent valleys, up to about 1,000 feet.
2. The Little Karroo, about 1,500 feet.
3. The Great Karroo, 1,500–2,500 feet, between the Zwartebergen and its continuations and the Great Escarpment.
4. The Upper Karroo, 3,000–4,000 feet, including the Cape Province north of the Great Escarpment, the east of Bechuanaland, and the west of the Orange Free State.
5. The High Veld, 4,000–6,000 feet, consisting of the north of the Orange Free State and the south of the Transvaal.
6. The Low Veld of the north and east of the Transvaal and the south and south-east of Southern Rhodesia in the wide open valley of the Limpopo and its tributaries, an unhealthy malarial lowland below 2,000 feet, unsuitable for white settlement, in strong contrast to the healthy uplands on the south and north.

Highest of all is the Drakensberg, the escarpment which overlooks Natal from heights of 10,000 feet; westward it falls

steeply through Basutoland, much of it over 8,000 feet, and then gradually to Bechuanaland and the Kalahari under 3,000 feet. Beyond this the levels rise again to 6,000 feet on the plateau of South-west Africa, and then drop very steeply on the escarpment to the narrow coastal desert. The coastal plain, 200 to 300 miles wide in Portuguese East Africa, narrows to less than 50 miles in British South Africa, and the escarpment behind it is prominently seen from the sea. The valleys of the Zambezi and the Limpopo carry the coastal climate far inland.

PRESSURE AND WINDS (Table, page 117)

South Africa is crossed by the sub-tropical high pressures centred about lat. 28° S. in winter, 33° S. in summer. In winter they are intensified over the cold dry interior, where the mean isobars (reduced to sea-level) show an anticyclone centred over the Orange Free State; calm and almost rainless weather and clear skies predominate. Southward pressure falls away in the westerlies of the Roaring Forties.

In summer the land is strongly heated by the overhead sun and pressure falls. The equatorial trough covers most of south Africa, breaking the sub-tropical high pressures which are represented by large anticyclones on the South Atlantic and South Indian Oceans, joined by a feeble belt off the south of the continent. The intertropical convergence swings south to the Transvaal.

The surface winds do not obey the sea-level isobars closely. Most of the plateau is 3,000 feet, much of it 5,000 feet, above the sea, so that the isobars fail to represent the actual pressure; a strong discontinuity divides the winds of the plateau and of the coasts and oceans. The steep, lofty, and continuous escarpment, only a few miles back from the sea, forces the winds to blow along rather than across the coast whatever the gradient, and increases their velocity. Another complication on the coast is the land- and sea-breezes, often strong enough to give a large component from the sea by day and a smaller one from the land at night. The winds reported at the early morning and afternoon observations differ on the plateau as well as on the coast; in winter, in the Union, they are light north-easterly at 0830, light north-westerly at 1500, and calms

are usual at night; in Rhodesia they are north-easterly to easterly all day with calms at night.

In winter the depressions of the westerlies, passing south of the Cape with their alternating air-masses of maritime tropical and maritime polar air, are felt strongly on the coasts as far north as lat. 30° S.; the south-west coast especially is exposed to their stormy fronts with variable winds (most between NW. and SW.), rain, and wild cold weather. The frequent 'North-westers' of the Cape region are of this type; their overcast skies and heavy rain are a feature of winter, and their gales are a serious danger to shipping in Table Bay which is fully exposed. A few of the disturbances extend far north in the interior also, even beyond Pretoria, with very cold weather, heavy rain, and occasionally snow, which, however, soon melts when the sun shines again. But the usual winter weather in the interior is fine, dry, and bracing, with almost cloudless skies and light winds. Southern Rhodesia has light to moderate easterlies, strong enough at times, however, to raise unpleasant dust. On the south-east coasts of the Union the winds are variable; south-westerlies predominate, but north-easterlies increase towards the east and predominate in Natal in the afternoon.

In addition to the depressions of the westerlies, coastal depressions, many shallow but some of moderate intensity, form in, or off, South-west Africa and travel round the Cape and then east, giving disturbed weather on the coasts.

In the summer months moist equatorial and maritime tropical air is drawn into the hot continent, and this is the season of cloud and rain everywhere except in the south-west of the Cape Province. On most of the plateau the surface winds are still northerly, backing from NE. in the forenoon to NW. in the afternoon; most nights are calm. The Karroo has easterlies in the morning, westerlies in the afternoon, and the Kalahari southerlies all day. In Rhodesia the wind is nearly always between N. and SE. On the south-west coasts southerlies are strongly predominant during the day; east of Cape Agulhas south-westerlies in the mornings give way to easterlies (NE. in Natal) in the afternoons.

The south-west of the Cape Province is under the influence

of the high pressures off the south of the continent, and has its fine-weather season, 7 almost rainless months with rarely a cloudy day; the stormy westerlies have retreated far to the south. But the gradient for SE. winds is often steep, and 'South-easters' blow strongly, at gale force in exposed places,

WIND DIRECTIONS, MEAN PERCENTAGE FREQUENCIES

	N.	*NE.*	*E.*	*SE.*	*S.*	*SW.*	*W.*	*NW.*	*Calm*
January									
Walvis Bay, 0830	21	6	2	0	4	2	1	5	58
1500	2	0	0	0	6	50	29	14	0
Cape Town, 0800	3	0	0	9	53	12	3	7	13
1500	1	0	0	5	64	11	8	10	1
East London, 0830	4	21	8	2	3	35	10	0	16
1500	0	24	25	13	18	18	2	0	0
Durban, 0600	17	4	0	0	7	27	4	7	33
1500	5	32	15	13	25	9	0	0	1
Johannesburg, 0830	27	16	12	2	3	1	1	16	23
1500	15	7	9	6	5	7	7	23	20
Salisbury, 24-hr. mean	17	30	16	13	6	1	3	8	6
July									
Walvis Bay, 0830	2	6	11	4	4	2	1	0	71
1500	3	1	1	0	17	53	8	9	8
Cape Town, 0800	27	7	1	9	13	3	3	9	28
1500	9	2	0	5	22	3	13	33	13
East London, 0830	15	4	0	0	0	8	24	41	8
1500	3	16	9	7	15	20	12	4	13
Durban, 0600	8	0	0	0	2	23	7	21	40
1500	4	38	10	12	20	8	1	0	6
Johannesburg, 0830	19	6	4	2	5	6	3	14	41
1500	15	7	6	6	4	12	9	21	20
Salisbury, 24-hr. mean	12	38	23	16	3	1	2	2	3

for days together; they are deflected by the topography into S. winds on the Cape Flats. The weather during south-easters is usually anticyclonic, the sky clear and the sunshine bright and continuous, except on ranges high enough to be cloud-capped (the 'Table-cloth' of Table Mountain). But a white haze of salt-particles and fine spray impairs visibility in the surface-layers on and near the sea, the naked hill-tops in the distance rising sharp and clear-cut above. South-easters occur in winter also and may bring cold spells, but they are much less frequent than in summer.

It should be noted that the high pressures mentioned above

are not permanent unchanging systems, but rather represent a procession of anticyclones, moving, often with considerable speed, from west to east. When one of them follows a deep depression it may give a powerful surge of maritime polar air on its east side, with heavy cloud and rain, so that the worst weather of the Cape Province (and the plateau in winter) is usually associated with a rising, not a falling, barometer. These polar outbursts travel far into low latitudes with the trade in the Indian Ocean.

The summer winds in Southern Rhodesia are light from the east, but with strong squalls in thunderstorms.

Temperature (Figs. 30, 31)

The mean temperature is remarkably uniform in British South Africa since the plateau is highest in the north and increase in latitude is balanced by decrease in altitude; moreover, cloud and rain decrease southward and the longer sunshine helps to compensate for the smaller angle of incidence of the insolation. The similarity of the means is shown in the table below, but it will be noticed that the maxima and minima vary considerably:

Mean Temperature

			Jan.			*July*			*Year*	
	Lat. S.	*Alt., feet*	*Daily max.*	*Daily min.*	*Mean for month*	*Daily max.*	*Daily min.*	*Mean for month*	*Mean for year*	*Annual range*
Salisbury	17° 48′	4,800	80	59	69	71	42	57	66	15
Pretoria	25° 47′	4,350	84	62	73	68	37	52	64	21
Bloemfontein	29° 8′	4,678	87	60	74	61	31	46	61	28
Graaff Reinet	32° 15′	2,442	91	60	75	66	43	54	66	21
Cape Town	33° 56′	40	81	61	71	63	48	55	63	16

South Africa is cooler than similar latitudes and altitudes in the north hemisphere, in part owing to its small area and the vastness of the adjacent oceans.

In winter (Fig. 30) the plateau is much colder than the coasts (July mean at Kimberley 51°, at Durban 64°), and frost is an important hazard for the farmer; its frequency and intensity depend on the topography, hollows holding lakes of cold air when the higher ground is warmer. The thermometer may fall well below freezing-point at night in the south of the plateau; in winter 'severe frosts, capable of freezing standing water, are practically unknown along the coast but are of

fairly frequent occurrence in the interior. As a matter of fact frost is liable to occur at inland stations during any month of the year, but more particularly from May till mid-September, although killing frosts are apt to occur as early as March and as late as October' (Fig. 29). In some cases the cold is a local effect on calm clear nights, in others southerly winds behind a

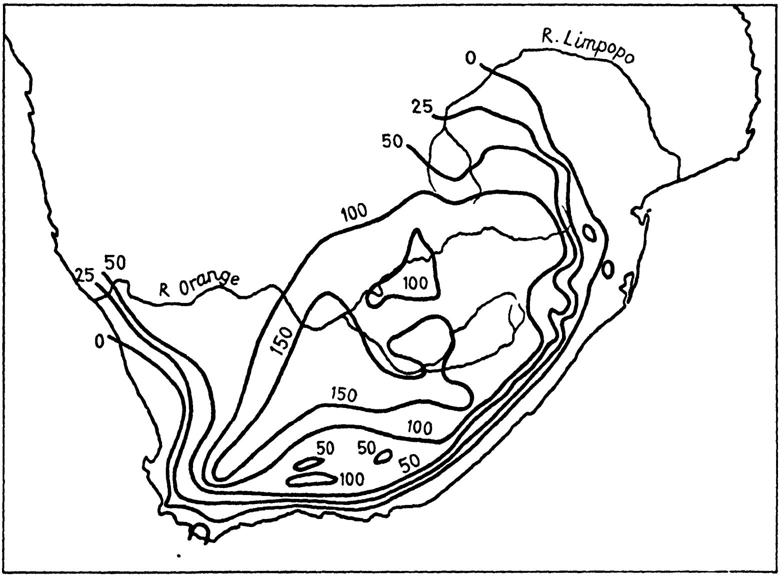


FIG. 29. Mean annual number of days with frost in South Africa.

low-pressure system import polar air, sometimes with rain or snow, which sweeps over large areas. Even the Rhodesian plateau is not immune from ground-frosts in winter, but the air temperature is very rarely below 32°, and snow is hardly seen except on the mountains. The lowest record is 6° at Carolina in the east of the Transvaal, altitude 5,600 feet.

The effects of the cool Benguela Current on the west and the warm Agulhas Current on the east and south are evident:

MEAN TEMPERATURE

	Feb.	*July*	*Year*
Port Nolloth	61	55	57
Cape Town	71	55	63
Port Elizabeth . . .	71	58	64
Durban.	76	68	70

The mean temperature of the surface of the sea near the shore changes little for 700 miles north of Cape Town, being lowest, about 57° in February, 55° in August, off the south of South-west Africa. In strong contrast the warm Agulhas Current is more and more prominent eastward from the Cape:

AGULHAS CURRENT, MEAN TEMPERATURE (APPROXIMATE) OF SURFACE WATER

	Feb.	*Aug.*
Off Cape Agulhas	69	61
„ Port Elizabeth	73	65
„ Durban	77	70
„ Beira	81	74

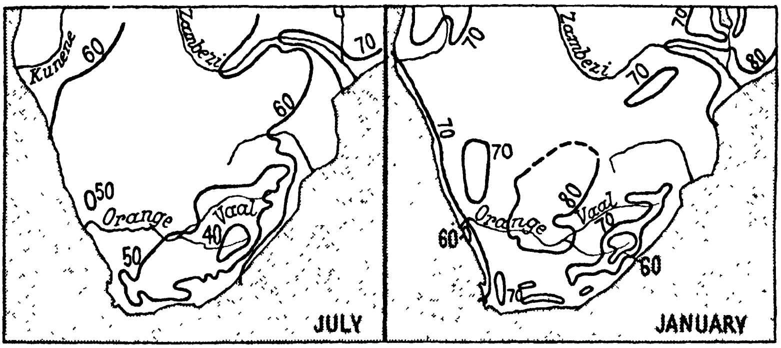


FIG. 30, 31. Mean isotherms (actual temperatures), south Africa.

In summer (Fig. 31), with its clear skies and long hours of powerful sunshine (for although summer is the rainy season it has not much rain or cloud) the plateau enjoys remarkably high day temperatures. The January mean is higher at Kimberley, altitude 3,996 feet, than at Durban on the coast which has much more cloud and rain (Fig. 32). The mean daily maximum in January at Pretoria (4,350 feet) is 84°, at Bloemfontein (4,615 feet) 87°; at Salisbury (4,865 feet) 85° in October, and readings over 100° occur even above 4,500 feet.

Spring is warmer than autumn on the plateau; at Kimberley the April mean is 64°, October 67°. Thus the temperature lags behind the sun less than is usual, a result partly of the clear skies and dry air, thanks to which the ground heats and cools rapidly, and partly of the fact that the summer rains have not started in spring but continue into autumn, so that April is cloudier than October. But on the coast autumn is

much warmer than spring. In Rhodesia the warmest month is October, before the clouds and rain reach their height and lower the temperatures, especially the maxima. Elsewhere January or February is the warmest month and July the coolest.

The range of temperature is far larger on the plateau than on the coast; on the plateau the annual range is least

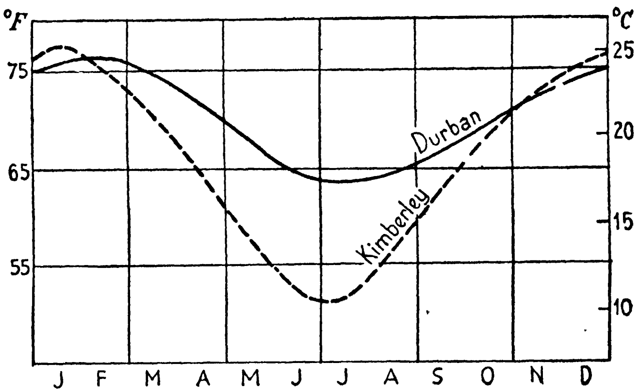


FIG. 32. Mean temperatures.

in the low latitudes of Rhodesia, and highest in the south, in the Free State and the Karroo. The daily range is high everywhere, the clear skies favouring hot days and cold nights, highest in the dry season, July and August on most of the plateau but January and February in the south-west of the Cape Province. It amounts to about 27° on the High Veld, being 26° at Pretoria (22° in January, 31° in July), 24° at Bulawayo (19° in February, 28° in September).

Berg winds. Hot and sometimes dusty winds known as Berg winds, carrying continental air to the coast, are noteworthy, especially on the cool west coast where their mean annual frequency is about 50 days. They come from the east in South-west Africa, from the north on the south coast, from the north-west in Natal. They are most frequent in the winter half-year, and bring abnormally high temperatures; 90° is common and 115° has been recorded at Port Nolloth. They may continue for as long as 2 or 3 days, with interruptions,

and can be very oppressive; the dry heat sometimes does much damage to crops. On the west coast they blow mostly in the morning and forenoon, the sea-breeze neutralizing them in the afternoon. Their high temperature seems to be due

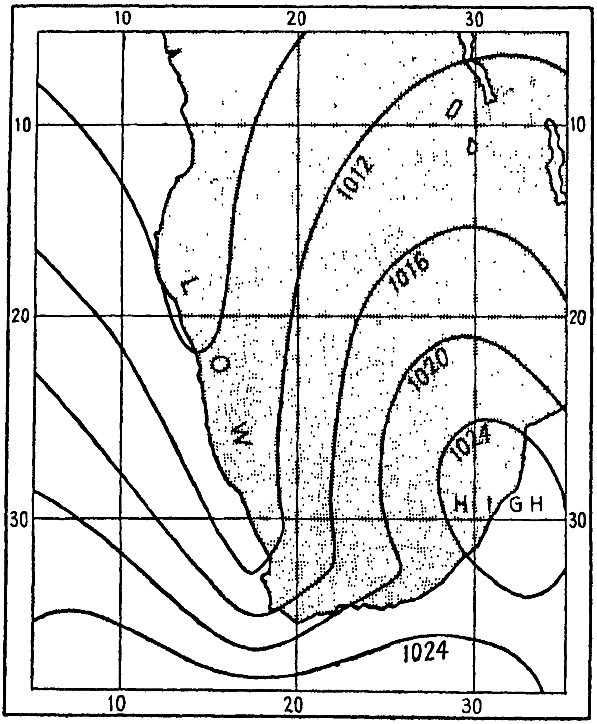


FIG. 33. Synoptic chart, 24 Mar. 1945; berg wind in the Cape Peninsula.

partly to descent of the air from the plateau. The usual subsidence of air in anticyclones is a factor, for the resulting inversion of temperature conduces to high surface temperature under strong sunshine; but it must be noted that these influences often operate far outside the places and times of berg winds. Fig. 33 shows the synoptic situation which gave a pronounced berg wind in the Cape Peninsula, temperature rising to 105° at Cape Town (where, however, the surface wind was light southerly, though the air was derived from the plateau on the north-east).

RAINFALL

Most of south Africa except the highest altitudes is arid or semi-arid, the rain being scanty and uncertain in amount and duration; only about 25 per cent. of the Union has a mean exceeding 25 inches. Southern Rhodesia is more favoured, having more than 25 inches in well over 60 per cent. of its area, and the rain is fairly reliable.

The greater part of the vapour, except in the south-west of the Cape Province, probably originates in the Indian Ocean, and is carried into the continent by the NE., E., and SE. winds. Summer is the rainy season, when the monsoonal effect is strongest and the surface air unstable. Tropical cyclones of the South Indian Ocean occasionally extend their influence over Rhodesia and add to its late summer rain. In general the east of south Africa gets fairly good totals, but the influence of relief shows itself strongly, as in the Low Veld of the Limpopo valley where the annual mean falls from over 40 inches on the High Veld of the north-east of the Transvaal to less than 15 inches, increasing again to over 35 inches on the highlands of Southern Rhodesia. The littoral of Natal has about 40 inches, and the highest parts of the Drakensberg between Giant's Castle and Mont aux Sources probably as much as 75 inches; the interior between the littoral and the Drakensberg has about 35 inches.

But beyond the Drakensberg the land-surface slopes down to the west and the rainfall decreases seriously, as is shown by the records from stations near the 29th parallel:

MEAN ANNUAL RAINFALL

	Alt. Feet	*Inches*
Durban	50	45
Pietermaritzburg	2,243	36
Drakensberg	10,000	45–75
Bloemfontein	4,583	21
Kimberley	3,996	16
Upington	2,640	7
Pella	1,500	3
Port Nolloth	22	3

Any latitude south of the Zambezi except in the south of the Cape Province shows a similar series. But the south and

south-west of the Cape Province is a region of much-broken relief, long and fairly lofty ranges, deep narrow valleys, and some wide open plains; consequently the rainfall is very varied. Moreover, the tendency here is for a decrease from west to east since the rain-bearing winds are from the west. Large areas of the mountains have more than 50 inches a year (the high west-facing slopes of the Drakenstein over 70 inches and probably 100 inches in places), but the totals fall to less than 30 inches on the more sheltered lowlands (Cape Town 25 inches) and in the enclosed valleys (Worcester 12 inches). The flat wheat-lands of the Malmesbury district, and the fertile tract east of the Hottentots Holland ranges, have about 20 inches. Not far east on the Karroo the annual means are not much more than 5 inches.

The 20-inch isohyet follows closely the west frontiers of Southern Rhodesia, the Transvaal, and Orange Free State, the country to the east having more than 20 inches. The highlands of Southern Rhodesia east of Gwelo have about 30 inches, and the amount increases rapidly to 50 inches in the mountains along the east frontier. In the Transvaal and the Free State the best-watered areas in the east have 30 to 35 inches. Most of Basutoland has between 25 and 35 inches, but the high Drakensberg over 60 inches; Swaziland has similar amounts. In the Cape Province the rainfall decreases from the south-east with more than 30 inches to the north-west with less than 5. Bechuanaland has between 10 and 20 inches except the south-west, where the annual mean falls to less than 5 inches as in the adjoining parts of the Cape Province; apart from this district the Kalahari 'desert' hardly merits its name, for it is a semi-arid tract with some poor grass and quantities of wild melons which provide drink for man and good food for cattle.

Not only is the rainfall heavier in the east, it begins earlier and goes on later than in the interior. Durban has rain in every month of the year, the really rainy season lasting 7 months, from October to April (Fig. 34). In the greater part of the interior where the total exceeds 25 inches the rains begin in October and last till March, a period of 6 months; April is a transition month, and the dry season definitely

starts in May. But in the drier region with 20 inches or less the rains are delayed till November and in many districts December, a delay which is a great disadvantage for agriculture. The difference in the yearly totals of two stations one west of the other is largely accounted for by the poor spring and early summer rains at the drier western station, e.g. Johannesburg and Vryburg:

Mean Seasonal Rainfall (inches)

	Winter June–Aug.	*Spring Sept.–Nov.*	*Summer Dec.–Feb.*	*Autumn Mar.–May*	*Year*
Johannesburg .	1·0	8·0	14·5	6·0	29·5
Vryburg . .	0·7	3·0	9·8	5·5	18·9

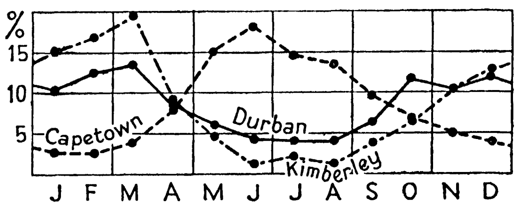


Fig. 34. Mean monthly precipitation, percentage of yearly total.

The east of Bechuanaland has an annual mean about 15 inches, but the rains are so short and unreliable that even native cattle-rearing is precarious.

However, in Southern Rhodesia the spring rain is similar everywhere (except that the elevated eastern escarpment receives more than the rest of the country), and the difference in the annual means arises chiefly from the better rains of late summer in the east:

	Winter June–Aug.	*Spring Sept.–Nov.*	*Summer Dec.–Feb.*	*Autumn Mar.–May*	*Year*
Salisbury .	0·2	5·3	21·7	6·2	33·4
Bulawayo .	0·1	3·9	15·0	4·6	23·6

The spring rains fall in local, instability thunderstorms, which are equally frequent in the east and west, and therefore the spring total is fairly uniform in amount. But the summer rain is brought by the general monsoonal inflow of N. and NE. winds, often of equatorial air, from the Indian Ocean which sets in about December, and the amount is naturally greater in the east. Such part of the autumn rain as is associated with

tropical cyclones of the South Indian Ocean is also largest in the east, but the heavy rains do not usually extend far inland.

Many stations in Southern Rhodesia have a slight break in the rains in the middle of December. This is not noticeable in

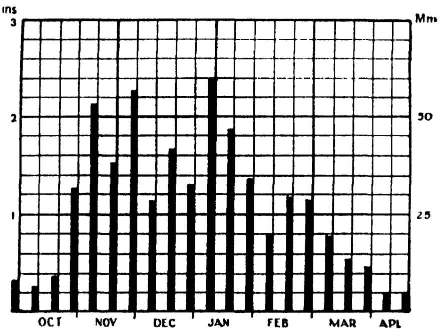


FIG. 35. Mean rainfall (10-day periods), Bulawayo (Goetz, 'The Rainfall of Rhodesia', *Proc. Rhodesia Sci. Assoc.*, 1909).

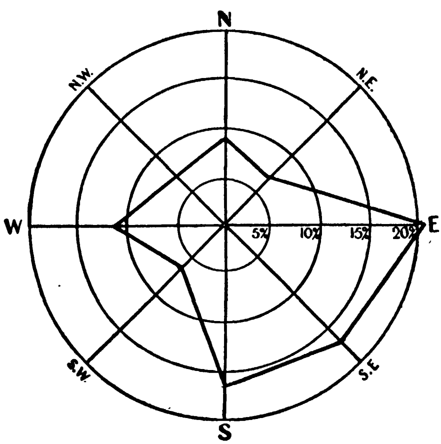


FIG. 36. Wind-rose (rainfall), Bulawayo (Goetz).

the monthly totals, but appears clearly in the means for 10-day periods (Fig. 35). It coincides with the retreat of the sun, and possibly the intertropical front, to the tropic, the rainiest periods being under the overhead sun. The rain-bearing winds are shown in Fig. 36.

Southern Rhodesia receives 94 per cent. of its rainfall in the summer half-year. Pretoria 88 per cent., Durban 68 per

cent. The line separating the summer- from the winter-rain maxima runs west from between East London and Port Elizabeth, through the Little Karroo and thence NNW. to the coast of South-west Africa between Lüderitz and Walvis Bay (Fig. 37). Cape Town has 78 per cent. of its rain in the

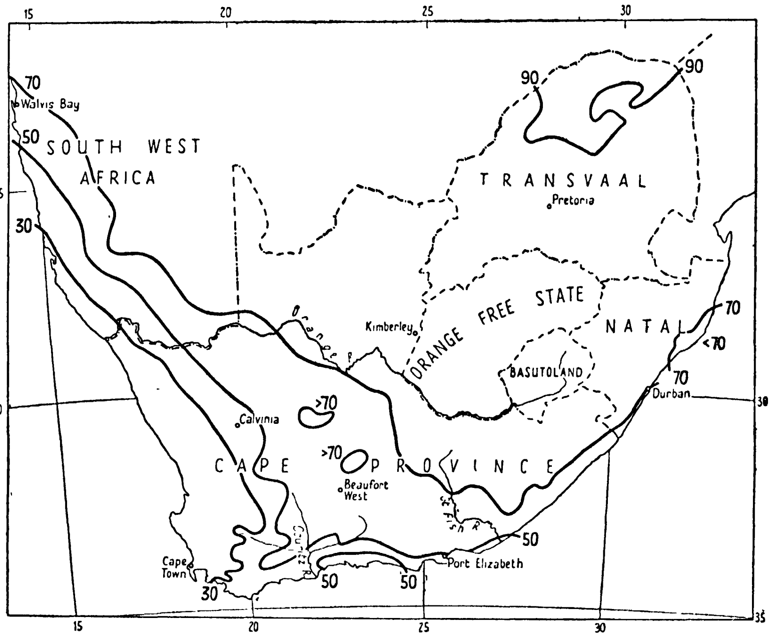


FIG. 37. Mean percentage of annual precipitation received in summer half-year (Union of South Africa, Meteorological Office).

winter half-year. Port Elizabeth with 55 per cent. in winter, 45 per cent. in summer, illustrates the transition. Most of the winter rain of this south-west region is brought by NW. winds, associated with the fronts of depressions of the Roaring Forties.

The thunderstorms of the plateau are violent and destructive. Groups of cattle may be killed by a single flash of lightning, and patches of grass fired. Hailstones of great size often fall at such times, and do much damage. Such destructive hailstorms are much rarer in Southern Rhodesia. A large part of the rain falls in thunderstorms, and much of it is lost to agriculture in the rapid run-off.

Another difficulty for the agriculturist is the unreliability of the rainfall:

ANNUAL RAINFALL (in.)

	Mean	*Highest record (1866–1936)*	*Lowest record (1866–1936)*
Cape Town (R. Obs.)	24·7	41·0	16·5
Bloemfontein	20·8	34·5	15·0
Durban	45·2	74·9	23·2
Kimberley	16·0	30·2	7·9
Prieska	9·3	18·7	1·4

Snow is hardly known on the coasts, but the mountains in the south above 4,000 feet, including large areas of the Drakensberg and the higher levels of the Cape Ranges, are sometimes snow-covered, the snow lying for a few days despite the dazzling sunshine.

SUNSHINE

In winter the air is very dry and the sky almost cloudless in the interior. At Johannesburg the mean cloud-amount in the months June to September is less than 2 tenths, and even the cloudiest month, February, has only 5; south Africa is justly famous for its sunny skies, a very striking feature of the climate to a visitor from north-west Europe:

MEAN DAILY SUNSHINE (hours)

	J.	*F.*	*M.*	*A.*	*M.*	*J.*	*J.*	*A.*	*S.*	*O.*	*N.*	*D.*	*Year*	*Per cent. of possible*
Kimberley	9·5	9·5	9·0	8·8	8·7	8·9	8·9	9·5	9·5	9·6	10·0	10·5	9·4	78
Cape Town	10·9	10·3	9·1	7·0	5·9	6·1	5·9	6·5	7·2	8·9	9·8	11·1	8·2	68
Port Elizabeth	8·1	8·2	7·4	7·4	6·8	6·8	7·0	7·5	7·3	7·8	8·1	8·7	7·7	64

In Southern Rhodesia, however, days of drab cloud and fairly strong E. winds are not unknown in winter, though a whole day with completely overcast sky is rare; the mean daily sunshine is about 9 hours in winter, 6 hours in summer. The large diurnal range of temperature on the plateau is a result of the clear skies. A drawback is the dust sometimes blown up by the wind from the dry ground, noxious for sufferers from lung troubles who find the climate very good in most respects. In Rhodesia the air is not only dusty in spring but hazy with smoke from bush-fires, making the sky grey. The only malarial districts are the coastal lowlands of north Natal, and the hot

damp valleys of the Zambezi and the Limpopo which carry the unhealthy climate far inland.

VISIBILITY

In spite of the dust and smoke-haze mentioned above, surface salt-haze on some coasts (p. 117), and industrial haze over the few large towns, visibility is in general good to very good:

PERCENTAGE OF OBSERVATIONS WITH GOOD OR VERY GOOD VISIBILITY (range 10 km. or more)

Cape Town, summer,	0830	74	Beaufort West, summer,	0830	94
	1500	94		1500	96
winter,	0830	63	winter,	0830	86
	1500	90		1500	87

MAJOR CLIMATIC REGIONS

The following regions (Fig. 38) may usefully be distinguished; the climatic means at representative stations are given on pages 139 and 145–6.

Regions 1 to 4 are coastal; they are distinguished from the interior by their much warmer and damper winters, free from the frost which is frequent on the plateau.

1 (representative station Port Nolloth); this southward continuation of the Namib of South-west Africa (p. 109) is an almost rainless desert dominated by the cool upwelling water off the coast which gives very cool summers, damp air, much fog and low cloud in late summer and autumn, but hardly any rain. Berg winds are remarkably warm in winter. Near the plateau the air is drier, fog is rare, and the summers are much warmer (mean temperature in February at Port Nolloth 61°, at Clanwilliam 77°), but the rainfall is still very scanty and the land is only poor steppe.

2 (Cape Town) is marked off from 1 by its heavier rainfall, and the 10-inch isohyet may be taken as the boundary. We have left the desert and reached a fairly well-watered land. Cape Town receives 25 inches a year, but the rainfall in this neighbourhood differs greatly according to locality, approaching 100 inches in small elevated areas near the town. Table Mountain is often capped with dense clouds during both north-westers and south-easters, the white cloud in the latter case being known as the Table-cloth. About 70 per cent. of the rain falls in winter, an unpleasant season owing to frequent

north-westers (p. 116) that give persistent rain, much of it a heavy drizzle, with overcast skies and often strong winds and chilly weather; many days, however, are almost cloudless, bright and warm. But only 5 months have mean rainfalls over 2 inches. The higher ranges sometimes bear deep snow.

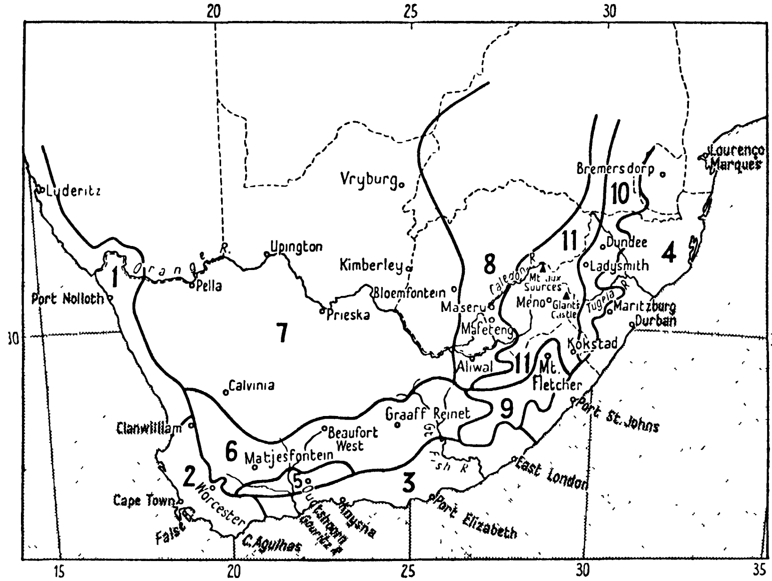


FIG. 38. Major climatic regions of South Africa.

Summer is dry but not quite rainless, sunny and often hot; but a disagreeable feature is the southerly wind which blows strongly, sometimes in south-easters of gale force for days, except in a few sheltered places such as Cape Town under the lee of Table Mountain; long slopes of white drift-sand up to some hundreds of feet above the sea-shore from which they are derived, and trees wind-bent towards the north-west, are visible signs of the force of the south-easters in the Cape Peninsula.

This 'Mediterranean' climate fosters some of the best agriculture of the Union; wheat is grown, vines flourish, favoured by the warm autumns and the mountain-shelter, to give the well-known wines of South Africa, and many fruits are produced, a large quantity being dried. But the summers are

much cooler than round the Mediterranean Sea in spite of the lower latitude; the mean temperature of the warmest month of the year is 76° at Tangier, 83° at Beirut, but only 71° at Cape Town owing to the oceanic situation and the cool Benguela Current. False Bay, only 15 miles distant across the Cape Flats, is often filled by the warm Agulhas Current and is then strikingly warmer than Table Bay; a sea-surface temperature of 67° has been observed in False Bay while it was only 51° in Table Bay.

3 (Port Elizabeth), the next division along the south coast, is distinguished by having moderate rain all the year (Fig. 38), with a mean total of 20 to 30 inches. Temperature is rather higher than in region 2, especially in winter in the east, and the range is less. The wind is notably strong, blowing from NE., often under a clear sky, as a depression approaches off the coast, and veering abruptly to SW. with cloud and rain when it passes. Agriculture and orchards are successful in a few areas with the help of irrigation.

4 (Durban) includes the Palm Belt of the Natal coast, subtropical in latitude but almost tropical in climate, thanks to warmth and moisture from the Agulhas Current; the mean monthly temperature ranges from 63° in winter to 76° in summer; summer is too damp, hot, and sultry for comfort, and winter is the season for holiday visitors. The pronounced cyclonic control of the weather in winter gives an alternation of NE. and SW. winds, the latter often setting in suddenly with very considerable or even gale force and heavy cloud and rain; in summer this control is still present but feebler, and spells of cool, cloudy, and rainy weather occur with S. winds. Sixty to seventy per cent. of the rain (mean total about 40 inches a year) falls in the summer half-year, but enough in winter to prevent that being a dry season.

The narrow littoral, not much more than 10 miles wide, with its heat and moisture is well suited for sugar-cane, the most valuable crop, and is the most useful tropical area of the Union; but the land rises rapidly into dissected hill country, much cooler, with grass, trees, and some cultivation, between the coast and the Drakensberg.

The remaining regions are inland, where altitude as well as continentality exerts a strong influence.

5 (Oudtshoorn), the Little Karroo, consists of the valleys of the Gouritz River and its tributaries, mostly about 1,500 feet above the sea and closely bounded by mountain-ranges so that the rainfall is reduced to less than 10 inches in places, and the land is so dry that it is of little value without irrigation; the clouds rising from the coast give rain on the mountains, from which they may often be seen descending in white curtains but evaporating after a few hundred feet. The powerful sunshine from cloudless skies makes the summer days intensely hot, but the winter nights are cold and often frosty.

6 (Graaff Reinet), the Great Karroo, is a shallow basin at an altitude of 2,000 to 2,500 feet, with a typical dry-plateau climate, very dry air, extremely hot summers, cool winters liable to invasions of cold polar air with occasional snow, and large range of temperature, both annual and diurnal, as everywhere on the plateau, the mean diurnal range rising to about 35° in January; Graaff Reinet has recorded 108° in summer, but frost is frequent in winter and may be severe. The region is largely bare rock and sand, furrowed with watercourses which are almost always dry, lightly clothed with stunted and dust-covered bushes, the picture of aridity. The mean annual rainfall is less than 5 inches in parts, and the Karroo has always been liable, like most of the plateau, to very long spells of even more than the usual drought:

> At last came the year of the great drought, the year of 1862. From end to end of the land the earth cried for water. Man and beast turned their eyes to the pitiless sky, that like the roof of some brazen oven arched overhead. On the farm, day after day, month after month, the water in the dams fell lower and lower; the sheep died in the field; the cattle, scarcely able to crawl, tottered as they moved from spot to spot in search of food. Week after week, month after month, the sun looked down from the cloudless sky, till the Karroo-bushes were leafless sticks, and the earth itself was naked and bare; and only the milk-bushes, like old hags, pointed their shrivelled fingers heavenwards, praying for the rain that never came (OLIVE SCHREINER).

7 (Calvinia) and 8 (Aliwal North) are the High Veld, most of it above 4,000 feet; they are separated by the 20-inch isohyet. The land is semi-arid in the east (8), arid in the west and north-west (7), most of it no better than desert west of

23° W., but improving to very poor steppe in favoured spots, with a wonderful display of flowers in good spring rains.

8, with 20 inches or more of rain, provides fair grazing for sheep, with some agriculture in the valleys which contain rivers. The mean temperature in January is about 70°, in July only 40° to 45°, the summers being almost as warm as in the Little Karroo 2,500 feet lower, but the winters much cooler.

9 (Mount Fletcher), the broken hill-country south-east of the Drakensberg, at altitudes between 3,000 and 6,000 feet, with a mean annual rainfall 20 to 40 inches, liable, however, like most of the Union, to long dry periods. About 80 per cent. of the rain normally falls in the summer half-year.

10 (Dundee, Ladysmith, Bremersdorp), the continuation of region 9 towards the north, and differing from it mainly in its heavier and less variable rainfall, and its warmer winters.

11 (Meno, Basutoland) is the highest part of south Africa, over 6,000 feet. It includes the mountainous protectorate of Basutoland, rising in the east to the Drakensberg (highest point 11,000 feet), a well-watered region (by south African standards) with precipitation up to 75 inches on the highest elevations to feed the head-waters of the Orange and Caledon Rivers. The higher altitudes have severe winters with much snow.

CLIMATIC MEANS

TEMPERATURE (°F.)

Mediterranean Africa

	Alt. feet	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year	Annual Range
Casablanca	56	*53*	54	57	59	62	68	71	**73**	71	67	60	56	63	20
Marrakech	1,542	*53*	55	60	65	69	75	83	**85**	77	71	59	55	67	22
Fez	1,050	*50*	52	56	59	65	71	79	**81**	75	67	55	51	63	31
Algiers	194	*53*	54	57	60	65	71	75	**77**	74	68	60	55	64	24
Sétif	3,540	*41*	42	48	54	60	71	**77**	75	69	59	49	43	57	36
Géryville	4,280	*39*	42	46	52	60	70	**78**	77	68	56	46	40	56	39
Tunis	108	*51*	51	56	60	67	74	79	**79**	76	68	59	53	64	28
Tripoli	56	*54*	56	60	65	69	74	79	**80**	78	74	65	58	68	26
Las Palmas (Grand Canary)	328	59	*59*	61	61	63	66	69	**71**	71	69	65	61	65	12
Funchal (Madeira)	82	59	*59*	59	60	63	65	69	**71**	71	68	64	61	64	12

The Sahara

	Alt. feet	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year	Annual Range
Biskra	410	*51*	55	60	67	75	84	**89**	88	82	70	59	52	71	38
Goléa	1,257	*49*	54	61	71	77	88	**93**	91	85	72	59	50	71	44
Touggourt	226	*51*	60	61	70	77	87	**92**	90	84	72	61	53	71	41
In Salah	919	*55*	59	68	76	86	94	**99**	97	92	80	68	58	78	45
Tamanrasset	4,429	*54*	58	64	72	78	83	**84**	83	79	74	65	58	71	30
Bilma	1,171	*61*	65	75	83	89	91	**91**	89	88	81	72	65	79	30
Port Étienne	13	*67*	69	69	69	71	73	73	77	**80**	76	73	68	72	13

The Sudan west of Lake Chad. The Guinea Lands

Coast	Alt. feet	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year	Annual Range
Dakar	131	73	73	73	73	75	81	82	81	82	82	80	75	78	9
Freetown	180	81	81	82	82	82	81	79	78	79	80	81	81	81	4
Accra	88	80	81	82	82	81	79	77	76	77	79	81	81	80	6
Lagos	10	81	83	83	83	82	79	78	78	79	80	82	82	81	5
Calabar	40	79	81	81	80	79	79	78	77	77	79	79	79	79	4
Interior															
Bamako	1,076	77	82	87	90	89	84	80	79	79	82	81	77	83	13
Ouagadougou	991	77	81	88	91	85	85	83	79	81	86	84	79	84	14
Gao	876	73	76	84	90	95	95	90	86	89	90	84	75	86	22
Lokoja	320	79	83	86	85	83	81	79	79	79	81	81	79	81	7
Zungeru	428	80	83	87	87	84	81	79	78	79	81	80	79	81	8
Kano	1,539	71	75	83	89	88	83	79	78	80	81	77	73	80	18
Zinder	1,676	72	77	85	91	93	90	83	81	84	87	81	75	83	21

The Sudan east of Lake Chad. Egypt

	Alt. feet	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year	Annual Range
Alexandria	105	56	57	60	64	69	74	77	79	77	73	67	60	68	23
Cairo (Ezbekiya)	67	54	56	61	68	75	80	81	81	77	72	65	57	69	27
Asyut	182	53	56	63	72	80	84	85	84	80	74	65	56	71	32
Wadi Halfa	410	61	63	71	80	87	90	90	90	87	83	73	63	78	29
Atbara	1,132	72	74	80	87	92	95	92	91	92	89	81	74	85	23
Khartoum	1,247	74	77	83	89	92	92	89	87	90	90	83	77	85	18
Malakal	1,280	81	83	87	88	85	81	79	79	81	82	82	81	82	9
Juba	1,509	84	85	85	84	81	80	78	78	80	81	82	83	82	7

TEMPERATURE (°F.)

The Sudan east of Lake Chad. Egypt—continued

	Alt. feet	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*	*Annual Range*
El Obeid	1,866	*67*	71	76	83	**86**	85	81	79	80	81	76	69	78	19
Wau	1,427	*80*	82	85	**86**	83	81	79	*79*	80	81	**81**	80	81	7
Kassala	1,640	*77*	79	84	89	**92**	90	84	*82*	85	**88**	85	79	85	15
Port Sudan	18	75	*74*	76	80	85	90	95	**95**	90	85	81	77	83	21
Quseir	23	66	*65*	69	75	81	85	86	**87**	85	82	75	67	77	22

Ethiopia (Abyssinia). Eritrea. Somaliland

	Alt. feet	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*	*Annual Range*
Harar	6,071	*66*	68	69	**69**	69	68	66	*65*	67	**68**	67	67	68	4
Addis Ababa	8,038	58	60	62	**62**	62	61	58	58	59	58	57	*56*	59	6
Berbera	45	*77*	77	80	84	88	97	**98**	97	93	84	80	77	86	21

Cameroons. French Equatorial Africa

	Alt. feet	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*	*Annual Range*
Fort Lamy	869	*74*	77	84	**91**	90	88	83	*80*	83	**85**	81	77	83	17
Yaundé	2,398	75	**77**	77	75	75	73	73	*72*	73	73	75	75	75	5
Duala	26	79	80	79	79	**81**	78	75	*75*	77	76	79	79	78	6
Libreville	115	80	80	**81**	81	80	78	*76*	77	78	78	79	79	79	5

The Belgian Congo

	Alt. feet	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*	*Annual Range*
Gemena	1,640	77	77	**78**	78	78	76	*75*	75	76	76	77	77	77	3
Tshibinda	6,939	61	**61**	61	61	61	59	*59*	59	61	61	61	60	61	2
Eala	1,115	78	**79**	78	78	78	77	73	*73*	77	77	77	77	77	6
Léopoldville	1,066	79	79	**80**	80	79	75	*73*	74	77	79	79	78	78	7
Elisabethville	4,035	71	72	71	69	65	61	*61*	65	71	**75**	74	72	69	14
Tshela	722	81	81	**83**	82	80	76	*71*	72	74	79	81	81	78	12

East Africa (Kenya, Tanganyika, Uganda)

Kenya	*Alt. feet*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*	*Annual Range*
Mombasa	52	82	83	84	82	79	78	77	77	77	79	81	82	80	7
Voi	1,837	79	80	81	79	76	74	73	73	74	77	78	78	77	8
Kabete (near Nairobi)	5,971	65	67	67	66	64	62	60	61	64	65	65	64	64	7
Nanyuki	6,389	61	63	63	63	62	61	60	60	61	61	61	60	61	3
Nakuru	6,024	65	67	67	66	65	64	63	63	63	64	64	64	65	4
Equator	9,062	57	58	58	57	57	55	53	53	55	56	56	55	56	5
Eldoret	6,863	63	64	65	64	63	61	60	60	61	63	63	62	63	5
Kisumu	3,769	75	76	75	75	73	72	71	73	73	75	75	75	74	5
Uganda															
Entebbe	3,878	72	72	72	71	71	70	69	69	70	71	71	71	71	3
Masindi	3,760	75	75	75	74	73	72	71	71	72	73	73	73	73	4
Tanganyika Territory															
Dar-es-Salaam	47	81	82	81	80	78	76	75	75	75	76	79	81	78	7
Tabora	4,151	73	73	73	73	72	70	70	72	76	78	76	73	73	8
Musoma	3,764	74	74	74	74	74	73	73	73	75	76	75	74	74	4
Mbeya	5,696	65	65	65	64	62	59	58	60	64	67	68	66	63	10

Angola

Luanda	150	78	80	80	79	77	72	69	68	71	75	77	75	75	12
Mossamedes	41	71	74	74	75	71	63	61	62	63	67	69	70	68	14

TEMPERATURE (°F.)

	Alt. feet	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year	Annual Range
Portuguese East Africa															
Mossuril (Mozambique) .	49	81	81	81	79	76	73	*72*	73	75	78	82	**82**	78	10
Beira	30	**81**	81	80	77	73	69	*68*	69	73	77	78	80	75	13
Lourenço Marques . .	194	77	**78**	76	73	69	65	*65*	66	69	72	74	77	72	13
Malema	2,133	77	77	77	75	71	67	*67*	69	75	80	**82**	79	73	15
Madagascar															
Tamatave . . .	20	80	**80**	79	77	74	71	*70*	70	72	75	77	79	75	10
Tananarive . . .	4,500	70	**70**	70	68	64	60	*58*	59	63	67	69	70	66	12
Tuléar	20	80	**81**	79	76	71	68	*67*	68	71	74	77	79	74	14
South-west Africa															
Walvis Bay . . .	24	66	**67**	66	65	63	61	58	*57*	57	59	62	65	62	10
Windhoek . . .	5,463	**75**	72	70	66	60	56	*55*	60	66	70	72	74	66	20
Northern Rhodesia. Nyasaland															
Abercorn . . .	5,440	67	68	68	68	67	64	*64*	66	70	**71**	69	68	67	9
Kasama	4,544	69	70	70	70	67	63	*63*	66	71	**75**	72	71	69	12
Broken Hill . . .	3,902	77	71	71	69	65	*61*	61	65	72	**77**	75	72	69	16
Zomba	2,948	72	72	71	69	66	63	*62*	65	69	74	**75**	73	69	14
Fort Johnston . . .	1,699	77	76	75	72	71	*69*	69	71	74	80	**80**	77	74	14
British South Africa (south of the River Zambezi)															
Southern Rhodesia															
Bulawayo . . .	4,393	71	70	69	66	61	*56*	57	60	66	**72**	71	70	66	16
Salisbury . . .	4,831	69	69	68	65	61	*57*	57	59	66	**71**	70	69	65	14

British South Africa (south of the River Zambezi)—continued

Transvaal	*Alt. feet*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*	*Annual Range*
Pretoria	4,375	**72**	71	69	63	57	52	*51*	57	63	69	70	71	64	21
Johannesburg	5,750	**69**	67	65	61	55	49	*49*	55	61	65	66	67	61	20
Komati Poort	486	**81**	81	78	74	69	64	*63*	68	72	76	78	80	74	18
Orange Free State															
Kimberley	3,996	**77**	75	71	65	58	52	*51*	56	62	69	72	76	65	26
Cape Province															
Port Nolloth	22	60	**61**	60	59	57	56	55	*55*	55	56	59	59	57	6
Cape Town (R. Obs.)	40	71	**71**	69	64	60	57	*55*	56	58	62	66	69	63	16
Port Elizabeth	176	70	**71**	68	66	62	59	*58*	59	60	63	65	69	64	13
Calvinia	3,240	**74**	72	68	61	56	51	*50*	52	55	61	64	70	61	24
Worcester	815	**73**	72	70	66	59	55	*53*	55	59	63	66	71	63	20
Victoria West	4,164	**72**	71	67	61	52	45	*45*	49	55	62	66	71	59	27
Graaff Reinet	2,460	**75**	75	71	66	60	56	*55*	58	62	66	69	74	65	20
Aliwal North	4,367	**70**	69	65	57	51	45	*45*	50	56	61	65	69	59	25
Natal															
Durban	50	76	**76**	75	72	68	64	*63*	65	67	69	71	74	70	13
Pietermaritzburg	2,243	71	**72**	70	66	61	57	*56*	60	63	67	69	71	65	16
Dundee	4,090	**70**	69	67	62	56	*51*	52	56	61	65	67	69	62	19
Kokstad	4,280	**67**	66	64	59	53	48	*48*	52	56	61	63	65	59	19
Protectorates															
Mbabane (Swaziland)	3,800	**68**	67	66	62	59	54	*53*	57	61	64	66	67	62	15
Mafeteng (Basutoland)	5,300	**69**	67	63	58	51	47	*45*	51	56	61	64	68	58	24

PRECIPITATION (inches)

	Alt. feet	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Mediterranean Africa														
Casablanca	56	1·5	1·8	2·3	1·5	0·7	0·4	<0·1	*<0·1*	0·1	1·1	**4·0**	2·9	16·3
Marrakech	1,542	0·8	1·0	1·7	0·9	0·6	0·3	*0·1*	0·1	0·4	0·7	**1·7**	0·7	8·9
Fez	1,050	1·8	2·7	3·2	2·3	1·7	0·4	*0·1*	0·1	0·4	2·2	**4·4**	3·6	22·9
Algiers	194	4·6	3·6	2·9	1·6	1·6	0·6	*0·1*	0·2	1·7	2·8	5·0	**5·1**	29·8
Sétif	3,540	**2·2**	1·7	1·6	1·0	1·9	0·9	0·6	*0·4*	1·6	1·9	2·0	2·1	17·9
Géryville	4,280	*0·9*	1·2	**2·4**	1·7	2·2	0·7	*0·2*	0·5	1·2	1·5	1·3	**1·5**	15·3
Tunis	108	2·1	2·0	1·8	1·5	0·9	0·5	*0·1*	0·2	1·0	1·9	2·0	**2·4**	16·7
Tripoli	56	3·7	2·1	1·0	0·6	0·3	<0·1	*<0·1*	0·1	0·5	1·5	2·3	**4·5**	16·5
Las Palmas (Grand Canary)	328	2·2	1·7	1·9	0·7	0·9	0·4	0·1	*0·1*	0·3	2·2	**3·3**	2·2	16·0
Funchal (Madeira)	82	*2·7*	**3·4**	3·1	1·7	0·9	0·3	*0·1*	0·1	1·0	3·7	**4·9**	3·5	25·4
The Sahara														
Biskra	410	0·9	*0·4*	**1·0**	0·3	0·7	0·2	*0·1*	0·4	**1·2**	0·9	1·0	1·0	8·1
Touggourt	226	*0·2*	0·4	**0·6**	0·1	0·2	0·1	0	0	0	0·2	**0·6**	0·4	2·8
Tamanrasset	4,429	0·3	0	0	0·2	**0·5**	0·2	0·1	0·4	0·1	0·1	0	0	1·9
Bilma	1,171	0	0	0	0	0	0	0·1	**0·4**	0·3	0	0	0	0·8
Agades	1,706	0	0	0	0	0·2	0·3	1·9	**3·7**	0·7	0	0	0	6·9
Port Étienne	13	0·1	0	0	0	0	0	0	0	0·3	**0·5**	0·1	0·4	1·5
The Sudan west of Lake Chad. The Guinea Lands														
Coast														
Dakar	131	<0·1	<0·1	<0·1	*0*	<0·1	1·1	3·5	**10·4**	5·7	1·7	0·2	<0·1	22·7
Bathurst	8	<0·1	*<0·1*	<0·1	<0·1	<0·1	2·8	9·9	**19·6**	10·1	2·9	0·2	<0·1	45·8
Conakry	16	*<0·1*	0·1	0·3	0·9	6·2	22·0	**51·1**	41·5	26·9	14·6	4·8	0·3	168·9

The Sudan west of Lake Chad. The Guinea Lands—continued

	Alt. feet	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Freetown	180	0·3	*0·2*	1·1	3·7	10·5	19·9	34·6	**35·0**	27·4	11·8	5·4	1·3	151·3
Abidjan	65	*1·6*	2·1	3·9	4·9	14·2	**19·5**	8·4	2·1	2·8	6·6	7·9	3·1	77·1
Accra	88	*0·6*	1·1	1·9	3·7	5·2	**7·0**	1·6	*0·6*	1·2	**2·3**	1·3	0·9	27·4
Lagos	10	1·1	2·1	3·7	5·7	10·5	**18·7**	10·7	*2·8*	5·3	**7·8**	2·6	*0·8*	71·7
Calabar	40	*2·1*	2·7	6·4	7·9	11·9	15·7	**16·9**	16·2	16·3	12·8	7·5	2·1	118·5
Interior														
Bamako	1,076	<0·1	*0*	0·1	0·6	2·9	5·3	11·0	**13·7**	8·1	1·7	0·6	0	44·0
Gao	876	<0·1	0	0·1	0·1	0·3	1·2	2·9	**3·6**	1·0	0·1	0	0	9·3
Ibadan	656	0·7	1·0	3·6	4·7	5·7	**8·7**	6·4	*3·1*	**7·4**	7·2	1·9	*0·4*	50·8
Lokoja	320	0·4	0·5	1·7	4·4	6·0	6·4	6·9	7·1	**9·3**	5·3	0·7	*0·2*	48·9
Zungeru	428	0	0	0·5	2·4	4·8	6·7	7·5	9·0	**10·8**	3·5	0·1	0·1	45·4
Bauchi	2,200	0	0	0·1	1·3	4·1	5·7	10·4	**11·6**	6·3	1·5	0	0	41·0
Kano	1,539	0	0	0·1	0·4	2·2	4·7	8·5	**12·6**	5·9	0·7	0	0	35·1
Zinder	1,676	0	0	0	<0·1	0·7	2·7	6·4	**8·4**	3·3	0·1	0	0	21·6

The Sudan east af Lake Chad. Egypt

	Alt. feet	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Port Said	11	**0·8**	0·5	0·4	0·2	0·1	0	0	0	0	0·1	0·5	0·7	3·3
Alexandria	105	**2·0**	0·9	0·4	0·1	0	0	0	0	0	0·2	1·3	**2·3**	7·4
Cairo (Ezbekiya)	67	**0·2**	0·2	0·2	0·1	0·1	0	0	0	0	0·1	0·1	0·2	1·1
Asyut	182	0	0	0	0	0	0	0	0	0	0	**0·1**	0	0·2
Wadi Halfa	410	0	0	<0·1	<0·1	<0·1	0	0	<0·1	0	<0·1	0	0	0·1
Atbara	1,132	0	0	0	<0·1	0·1	<0·1	0·7	**1·5**	0·2	<0·1	0	0	2·8
Khartoum	1,280	0	0	0	0	0·1	0·4	2·0	**2·9**	0·7	0·2	0	0	6·3
Sennar	1,378	0	0	0	0·1	0·9	2·4	4·7	**6·3**	2·8	0·7	<0·1	0	17·9
Malakal	1,280	*0*	0	0·2	1·2	3·1	5·1	6·9	**7·2**	5·4	2·9	0·4	<0·1	32·5
Juba	1,509	*0·2*	0·6	1·3	4·8	**5·9**	5·3	*4·8*	**5·2**	4·2	3·7	1·4	0·7	37·9
El Obeid	1,847	0	0	0	0	0·7	1·5	3·8	**4·6**	3·0	0·6	0	0	14·2

PRECIPITATION (inches)—*continued*

The Sudan east of Lake Chad. Egypt—continued

	Alt. feet	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
El Fasher	2,395	0	0	0	0	0·4	0·7	4·5	5·4	1·2	0·2	0	0	12·4
Wau	1,427	<0·1	0·2	0·9	2·6	5·3	6·5	7·5	8·2	6·6	4·9	0·6	<0·1	43·4
Roseires	1,526	0	<0·1	<0·1	0·6	2·4	5·0	7·3	8·7	6·1	1·2	0·2	0	31·8
Kassala	1,640	0	0	<0·1	0·1	0·5	1·2	3·6	4·9	2·3	0·3	0	0	12·9
Port Sudan	18	0·3	0·2	0	0	0	0	0·2	0·2	0	0·6	1·8	1·0	4·3
Quseir	23	0	0	0	0	0	0	0	0	0	0	0·2	0·1	0·3

Ethiopia (Abyssinia). Eritrea. Somaliland

	Alt. feet	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Gambela	1,345	0·2	0·4	1·4	3·2	5·9	6·7	8·5	9·4	7·3	3·5	1·8	0·4	48·9
Harar	6,071	0·4	1·3	3·0	4·7	5·0	3·5	5·1	6·3	3·7	1·4	0·6	0·4	35·3
Addis Ababa	8,038	0·5	1·5	2·6	3·4	3·4	5·3	11·0	11·8	7·5	0·8	0·6	0·2	48·7
Massawa	64	1·7	0·7	0·6	0·2	0·3	0	0·1	0·4	0·2	0·4	1·0	1·7	7·3
Berbera	45	0·2	0·2	0·5	0·5	0·3	0·1	0·1	0·1	0·1	0·1	0·2	0·1	2·5
Mogadishu	39	0	0	0	2·6	2·8	3·7	2·8	2·1	1·4	1·2	1·7	0·7	19·0

Cameroons. French Equatorial Africa

	Alt. feet	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Fumban	3,881	0·1	0·9	2·0	5·1	10·0	5·7	11·3	11·4	12·6	9·6	2·4	0·1	71·3
Yaundé	2,398	0·6	1·1	6·7	7·0	9·0	8·0	3·8	2·2	9·2	12·3	4·2	1·5	65·6
Debundja	33	7·5	11·3	16·2	15·9	24·3	51·6	59·1	54·5	55·7	43·5	22·6	11·5	373·9
Duala	26	1·8	3·7	8·0	9·1	11·8	21·2	29·2	27·3	20·9	16·9	6·1	2·5	158·5
Libreville	115	10·5	10·4	13·8	13·0	9·6	0·7	0	0·8	3·9	11·3	14·6	8·6	97·2

The Belgian Congo

	Alt. feet	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Gemena	1,640	0·7	2·6	4·2	7·0	5·9	7·6	5·4	8·3	6·4	11·0	5·3	2·2	66·5
Tshibinda	6,939	7·4	7·5	7·7	10·1	6·3	2·6	1·1	2·2	6·0	9·6	7·1	8·0	75·6

The Belgian Congo—continued

	Alt. feet	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Léopoldville	1,066	5·3	5·7	7·7	7·7	6·2	0·3	0·1	0·1	1·2	4·7	8·7	5·6	53·3
Stanleyville	1,404	1·7	2·7	7·2	6·9	5·6	4·0	5·2	5·8	7·2	8·2	7·2	3·7	65·4
Kongolo	1,893	5·7	3·3	5·9	3·6	1·2	0·2	0·4	2·5	2·3	4·8	5·5	8·4	43·8
Elisabethville	4,035	9·1	9·5	8·7	1·7	0·2	0	0	0	0·1	1·1	4·8	10·1	45·3
Matadi	285	5·4	4·3	6·6	7·4	2·4	0	0	0·1	0·3	1·1	6·7	5·8	40·1
Boma	62	7·0	6·3	3·4	7·9	2·8	0	0	0·1	0·6	1·2	8·9	5·3	45·2

East Africa (Kenya, Tanganyika, Uganda)

	Alt. feet	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Kenya														
Mombasa	52	1·0	0·7	2·5	7·7	12·6	4·7	3·5	2·5	2·5	3·4	3·8	2·4	47·3
Voi	1,837	1·3	1·2	3·0	3·8	1·3	0·3	0·1	0·3	0·5	0·9	3·8	5·1	21·7
Kabete (near Nairobi)	5,971	1·5	2·5	4·9	8·3	6·2	1·8	0·6	0·9	1·2	2·1	4·3	3·4	37·9
Nakuru	6,024	0·7	1·5	2·6	5·0	4·5	3·3	4·4	4·1	2·7	2·2	2·5	1·2	34·6
Equator	9,062	0·7	1·6	3·5	5·8	5·7	5·0	5·9	7·6	3·9	1·3	3·4	1·5	45·8
Eldoret	6,863	0·7	1·9	2·3	4·5	4·8	4·2	7·3	7·5	3·1	1·2	1·9	1·1	40·3
Wajir	850	0·2	0·3	0·8	2·1	1·1	0·1	0·2	0·1	0·3	0·9	1·9	0·9	8·9
Nyeri	6,000	1·7	1·8	2·8	7·2	7·1	1·4	1·4	1·4	1·2	3·6	4·3	2·9	36·7
Lodwar	1,660	0·1	0·3	0·7	1·5	1·1	0·4	0·5	0·2	0·1	0·1	0·3	0·4	5·7
Kisumu	3,769	1·6	3·2	6·8	6·0	7·7	4·3	2·4	4·1	2·4	1·9	4·3	3·2	47·8
Kericho	6,700	2·9	4·6	6·0	9·5	10·5	6·3	6·3	7·4	5·9	5·2	4·3	2·6	71·5
Uganda														
Kampala	4,304	1·8	2·4	5·1	6·9	5·8	2·9	1·8	3·4	3·6	3·8	4·8	3·9	46·2
Mbarara	4,734	1·5	2·6	3·7	4·6	2·9	0·9	0·9	2·5	3·9	4·0	4·5	2·9	35·0
Mubende	5,095	1·5	2·4	4·1	5·9	4·1	2·4	2·2	4·9	5·5	6·0	5·5	2·7	47·3
Fort Portal	5,049	1·2	3·0	5·5	7·3	5·4	3·0	2·1	4·6	7·5	8·3	6·5	2·8	57·2
Butiaba	2,037	0·5	1·4	2·3	4·0	4·2	2·3	2·7	3·6	3·1	3·3	2·9	1·1	31·3
Rhino Camp	2,000	0·5	1·3	3·3	5·5	4·1	3·2	3·6	7·6	4·3	6·0	3·2	1·0	43·7
Gulu	3,650	0·4	2·0	3·5	6·7	8·3	5·7	6·1	8·5	6·7	6·3	3·8	1·7	59·6

PRECIPITATION (inches)—*continued*

East Africa (Kenya, Tanganyika, Uganda)—continued

Tanganyika Territory	*Alt. feet*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*
Dar-es-Salaam	47	2·8	3·2	5·6	11·8	7·4	1·1	1·1	*1·1*	1·4	2·3	2·7	3·1	43·7
Lindi	127	6·0	*4·2*	7·0	7·2	1·5	0·5	0·3	*0·3*	0·5	0·3	2·5	6·7	36·9
Amani	2,989	3·3	*3·1*	6·7	14·2	13·4	4·8	*3·9*	3·9	4·0	6·1	6·6	6·5	76·5
Tabora	4,151	*4·9*	5·1	6·8	5·1	1·2	0·1	*0*	0	0·3	0·6	4·2	6·7	35·1
Musoma	3,764	*2·1*	2·7	4·5	6·3	4·1	0·8	*0·5*	0·9	1·0	1·4	2·9	2·5	29·6
Bukoba	3,753	*5·9*	6·6	10·4	13·3	13·0	3·6	*1·5*	3·2	3·9	4·8	6·3	7·1	79·7
Kigoma	2,903	*4·8*	5·0	5·9	5·1	1·7	0·2	*0·1*	0·2	0·7	1·9	5·6	5·3	36·6
Mbeya	5,696	7·5	6·6	7·1	4·4	0·7	0·1	*0*	0·1	0·1	0·5	2·2	5·4	34·8
Angola														
Luanda	150	1·3	1·4	3·0	4·7	0·5	0	0	0	0·1	0·2	1·1	0·9	13·2
Mossamedes	41	0·3	0·4	1·0	1·3	0	0	0	0	0	0	0·1	0·1	3·2
Portuguese East Africa														
Mossuril (Mozambique)	49	8·8	9·1	5·8	3·0	1·1	0·7	0·4	0·5	0·4	*0·2*	0·9	3·9	32·9
Beira	30	10·3	9·6	9·5	4·4	2·5	1·3	0·8	1·0	*0·6*	1·6	4·7	9·9	56·4
Lourenço Marques	194	5·3	5·3	5·8	2·0	1·3	0·5	*0·6*	0·6	0·9	1·8	3·3	4·5	31·8
Ribaue	1,770	11·5	10·9	7·6	1·8	0·5	0·7	0·4	*0·4*	0·6	0·9	1·9	6·3	43·5
Madagascar														
Tamatave	20	13·9	14·3	17·2	15·2	10·7	10·7	11·4	7·6	5·0	*3·8*	4·5	9·9	123·3
Tananarive	4,500	11·8	11·2	7·1	2·1	0·6	0·3	*0·3*	0·4	0·7	2·4	5·3	11·3	53·5
Tuléar	20	3·8	3·6	1·6	1·2	1·2	0·6	0·4	*0·2*	0·4	0·5	0·8	2·4	16·6

	Alt. feet	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
South-west Africa														
Walvis Bay	24	0	0	0·1	0·1	0	0	0	0	0	0	0	0	0·3
Windhoek	5,463	3·1	2·9	2·8	1·4	0·2	0	0	0·1	0·1	0·4	0·8	1·8	13·6
Karibib	3,839	1·6	1·7	1·7	0·7	0·1	0	0	0	0	0·2	0·3	0·9	7·2
Northern Rhodesia. Nyasaland														
Kasama	4,544	10·7	9·9	10·9	2·8	0·6	0	0	0	0	0·8	6·4	9·5	51·6
Mongu	3,459	8·7	7·7	6·3	1·5	0	0	0	0	0·1	1·4	3·9	7·9	37·4
Broken Hill	3,902	10·6	7·9	5·0	0·8	0	0	0	0	0·1	0·7	3·7	8·2	37·1
Livingstone	3,161	6·5	5·8	3·8	1·1	0·1	0·1	0	0	0·2	0·8	2·7	5·6	26·7
Zomba	2,948	11·2	9·7	9·1	3·4	0·9	0·5	0·3	0·4	0·3	1·2	4·8	10·7	52·6
Fort Johnston	1,699	7·4	7·8	5·1	1·5	0·1	0·1	0·2	0	0	0·2	1·5	6·3	30·2
Nkata Bay	1,400	8·3	14·5	13·0	11·9	3·0	2·3	1·2	1·0	0	0·4	0·4	1·0	57·0
British South Africa (south of the River Zambezi)														
Southern Rhodesia														
Bulawayo	4,405	5·5	4·7	3·5	0·7	0·4	0·1	0	0	0·2	0·7	3·0	4·8	23·6
Salisbury	4,885	7·7	6·9	4·7	1·1	0·4	0·1	0	0·1	0·2	1·1	4·0	7·1	33·4
Chipinga	3,694	10·1	7·9	7·3	2·2	0·9	0·7	0·7	0·7	0·7	1·6	4·8	7·5	45·1
Transvaal														
Pretoria	4,350	5·4	4·2	3·6	1·2	0·6	0·1	0·3	0·5	0·6	2·5	4·7	4·4	28·3
Johannesburg	5,925	5·5	4·3	3·8	1·5	0·7	0·2	0·4	0·4	0·9	2·4	4·7	4·7	29·5
Graskop	4,880	10·7	10·9	10·1	3·8	1·7	0·7	1·0	0·9	1·2	3·6	7·6	8·2	60·4
Orange Free State														
Kimberley	3,996	2·4	2·5	3·1	1·4	0·7	0·2	0·3	0·2	0·6	1·0	1·6	2·0	16·0
Odendaalsrust	4,440	3·0	2·7	3·1	1·2	0·5	0·2	0·2	0·3	0·6	1·7	2·7	2·0	18·1
Bloemfontein	4,583	3·5	3·1	3·5	1·8	1·0	0·4	0·3	0·4	0·8	1·5	2·1	2·3	20·8
Bethlehem	5,400	3·7	3·3	3·1	1·2	0·7	0·2	0·3	0·5	0·9	2·1	2·4	3·4	21·8

PRECIPITATION (inches)—*continued*

Cape Province	*Alt. feet*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*
Port Nolloth . .	22	0·1	0·1	0·2	0·2	0·4	**0·4**	0·3	0·3	0·2	0·1	0·1	0·1	2·5
Cape Town (R. Obs.)	40	0·7	*0·6*	0·9	1·9	3·7	**4·4**	3·6	3·3	2·3	1·6	1·1	0·8	24·7
Port Elizabeth. .	176	*1·2*	1·3	1·9	1·9	2·4	1·7	1·9	2·1	**2·4**	2·3	2·1	1·7	22·7
Pella . . .	1,500	0·2	0·5	**0·7**	0·3	0·3	0·2	*0·1*	0·1	0·2	0·1	0·2	0·2	3·1
Calvinia . . .	3,240	0·3	0·5	0·8	0·8	1·1	**1·2**	1·0	0·9	0·6	0·5	0·4	*0·2*	8·2
Worcester . .	815	*0·3*	0·4	0·5	1·0	1·5	**2·1**	1·7	1·5	1·1	1·0	0·5	0·4	11·9
Matjesfontein . .	2,970	0·3	0·4	0·6	0·7	0·8	**1·0**	0·6	0·6	0·5	0·5	0·3	*0·3*	6·6
Oudtshoorn . .	1,090	*0·5*	0·7	**1·2**	0·9	0·9	0·7	0·6	0·8	1·0	0·8	0·8	0·6	9·5
Graaff Reinet . .	2,460	1·3	1·9	**2·2**	1·1	1·0	0·5	*0·5*	0·6	0·9	1·1	1·5	1·4	14·1
Aliwal North . .	4,367	3·4	3·5	**3·9**	1·9	1·0	0·6	*0·5*	0·8	1·0	1·5	2·3	2·7	23·1
Mafeking . .	4,169	**3·6**	3·2	3·2	1·1	0·5	0·2	*0·2*	0·4	0·6	1·4	2·8	3·5	20·5
Natal														
Durban . . .	50	4·6	5·3	**6·0**	3·6	2·6	1·8	*1·7*	1·8	2·8	5·1	4·7	5·2	45·2
Pietermaritzburg .	2,243	5·6	4·9	5·3	1·9	1·0	0·5	*0·5*	1·0	1·9	3·4	4·4	**5·7**	36·1
Ladysmith . .	3,279	**5·3**	4·7	4·2	1·3	0·6	*0·3*	0·4	0·8	1·2	2·7	3·5	4·8	29·3
Dundee . . .	4,090	**5·4**	4·8	4·1	1·7	0·7	*0·3*	0·3	0·7	1·4	2·9	4·3	5·2	32·1
Mount Fletcher .	4,800	**4·9**	4·3	3·9	1·4	0·8	0·5	*0·5*	0·6	1·4	1·9	3·0	4·4	27·7
Protectorates														
Bremersdorp (Swaziland) . . .	2,054	**6·4**	4·8	4·8	2·0	0·9	*0·3*	0·5	0·8	1·5	3·1	4·3	5·6	35·0
Mbabane (Swaziland)	3,816	**9·9**	7·6	7·9	2·6	1·3	*0·5*	0·9	1·1	2·1	5·0	6·8	8·4	54·0
Maseru (Basutoland)	5,168	**4·7**	4·2	4·4	2·2	1·1	0·7	*0·5*	0·6	1·5	2·3	3·3	3·5	29·0
Meno (Basutoland) .	7,700	3·5	4·5	3·6	1·7	1·3	*0*	0·5	0·3	0·6	1·5	4·6	**4·6**	26·7

PART III

ASIA (WITH EUROPEAN RUSSIA, FINLAND, BALTIC STATES)

CHAPTER XVIII

GENERAL FEATURES

Asia, the largest continent, has an area of seventeen and a quarter million square miles, and from a meteorological point of view the land-mass is considerably larger, since Europe and north Africa must be included. It belongs essentially to middle latitudes; only the southern peninsulas project south of the tropic, without reaching the equator though Singapore is almost on the line.

The core of the continent consists of vast plateaux, buttressed by ranges of mountains. Trans-Caspia and Siberia are low plains, lying north of the central mountains and plateaux and thus cut off to a large extent from southern influences, since the barrier is high enough to form a more or less impassable wall in the lower strata of the atmosphere. For this reason the winters are exceedingly cold in the north of these plains, the 'cold pole' of the earth being in the north-east of Siberia on the Arctic Circle (Fig. 40); they are colder than in the corresponding part of Canada, where the absence of a transverse barrier permits mild winds from the south to moderate the winter cold.

Pressure and Winds

The winter cold intensifies the sub-tropical high pressures in south Asia; but the prominent feature is the 'cold' anticyclone, a cushion of very cold, dry, dense air centred over the Gobi, which is an extension and intensification of the Arctic high pressures (Fig. 41, January). The main current of the westerlies is deflected round the north of this high-pressure system, the middle of which has lighter winds.

In summer the land heats rapidly and the large winter anticyclone is entirely dissipated; the normal sub-tropical high

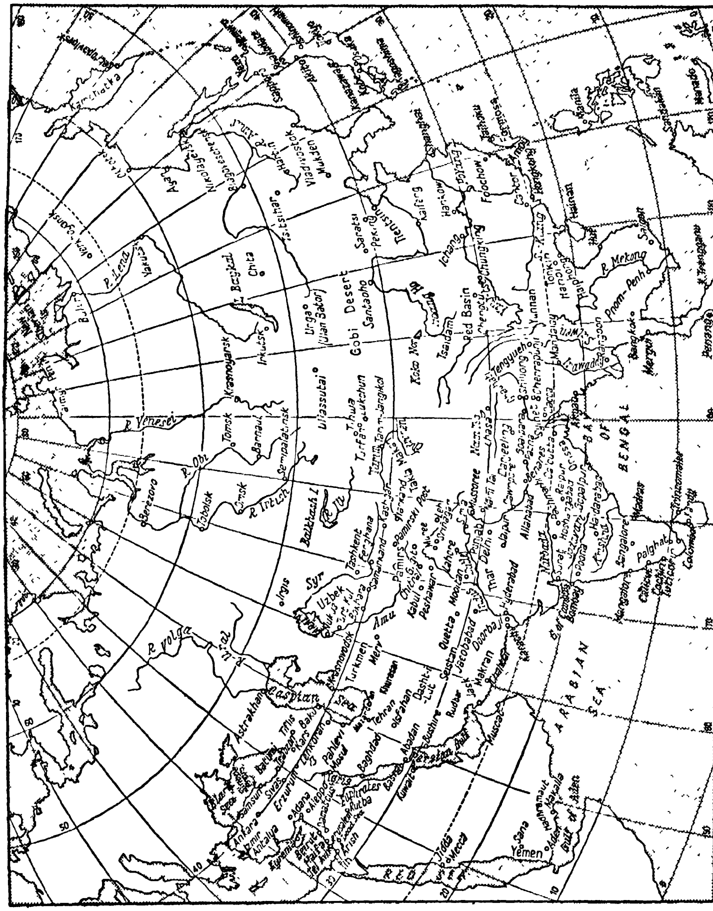


FIG. 39. Place-names mentioned in the text. For China see Fig. 73; Japan, Fig. 76; Indonesia, Fig. 77a; Russia, Fig. 93.

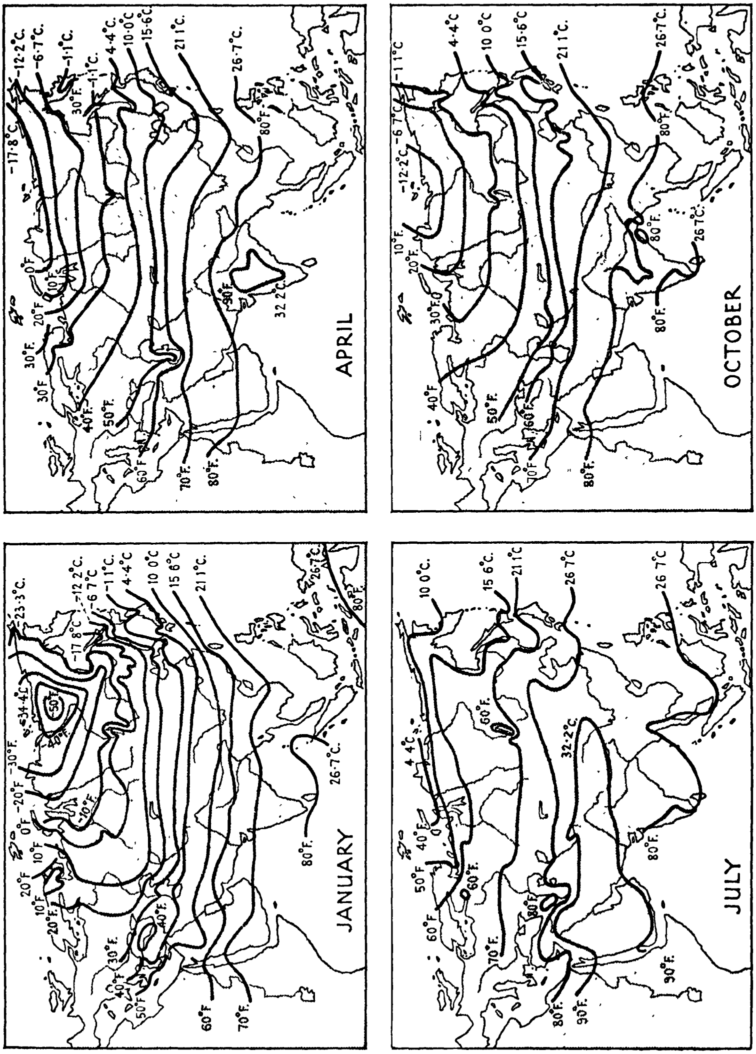


FIG. 40. Mean isotherms.

pressures in the south are changed to low (Fig. 42, July). The centre of lowest pressure is over Baluchistan and Sind, and a vast north-eastward extension covers the interior of

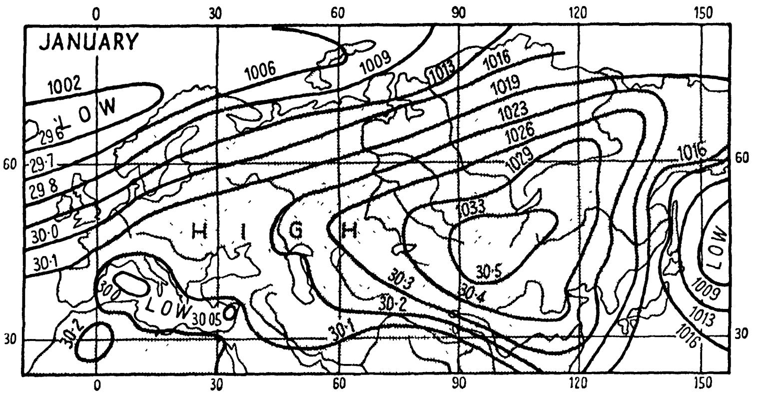


FIG. 41. Mean isobars, January; for the Indian region see Fig. 48 (note, in lat. 60° N., long. 150° E., *for* 1016 *read* 1019).

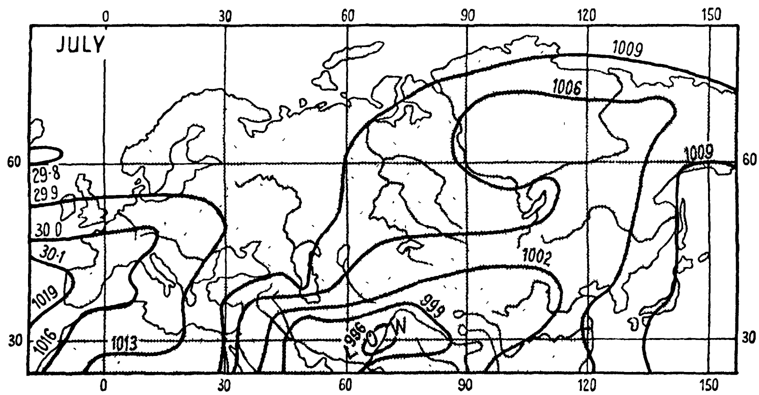


FIG. 42. Mean isobars, July.

the continent. The pressure change from winter to summer is the largest found on the globe, and the resulting seasonal change of wind is remarkably complete. The climate of south Asia is often taken as typical of a monsoonal régime, but this is somewhat misleading, since the conditions here are unique. North America is the only comparable continent, and there the monsoonal reversal of pressure, wind, and weather is

much less complete, owing partly to the nature of the relief and partly to the smaller area.

Climatically, perhaps the most striking phenomenon in Asia is the rainy summer monsoon. In general, summer is the rainy season, and winter is almost or quite rainless (Figs. 43 to 47).

It will be the aim of the chapters which follow to point out

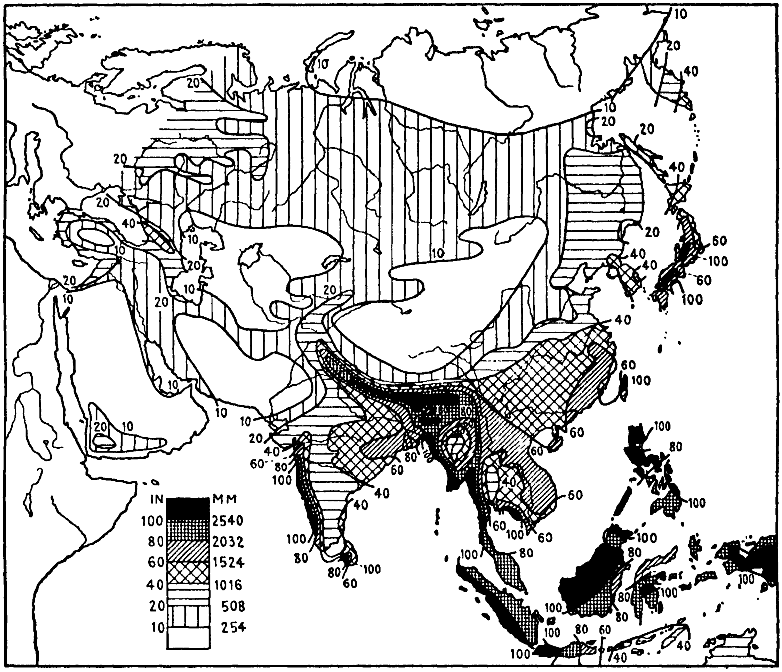


FIG. 43. Mean annual precipitation.

the main differences in the meteorology and climate of the monsoon countries, to indicate the contrasts between the tropical and the extra-tropical monsoons, and to show that while the winter monsoon is the dry season in most areas, it gives much rain in certain regions, the west of Japan, part of China, the coast of Annam, the Malay Peninsula, and the east of Ceylon. In the Indian region as a whole the distinction between rainy summer and dry winter holds good, yet in every month of the year some part of that country is receiving rain which is valuable economically.

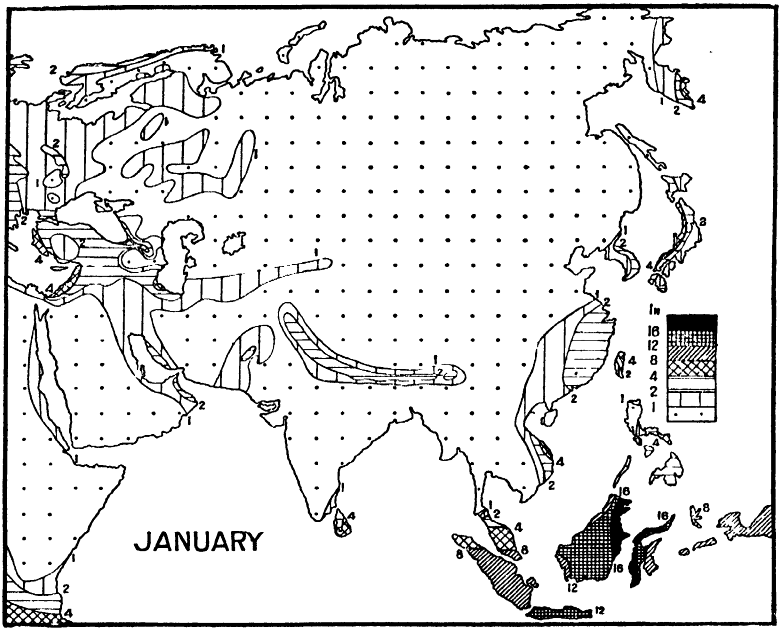


FIG. 44. Mean precipitation, January (Herbertson).

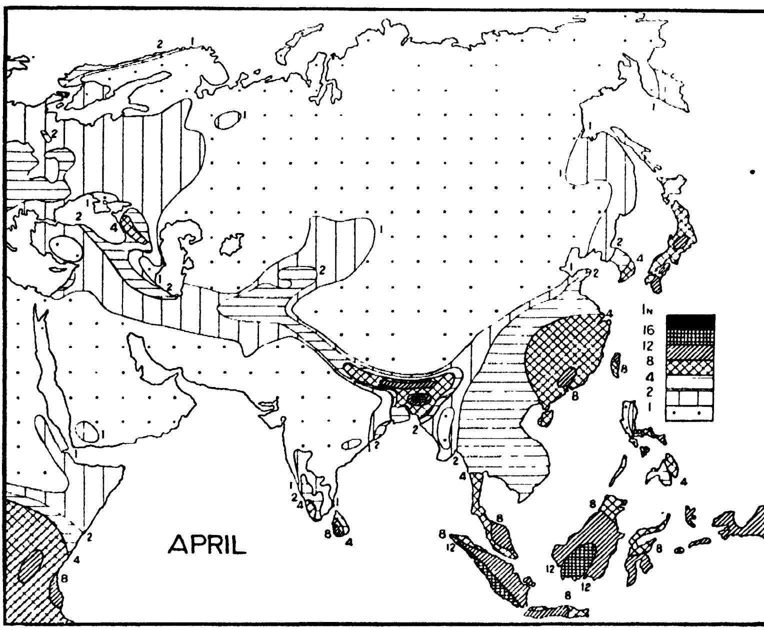


FIG. 45. Mean precipitation, April (Herbertson).

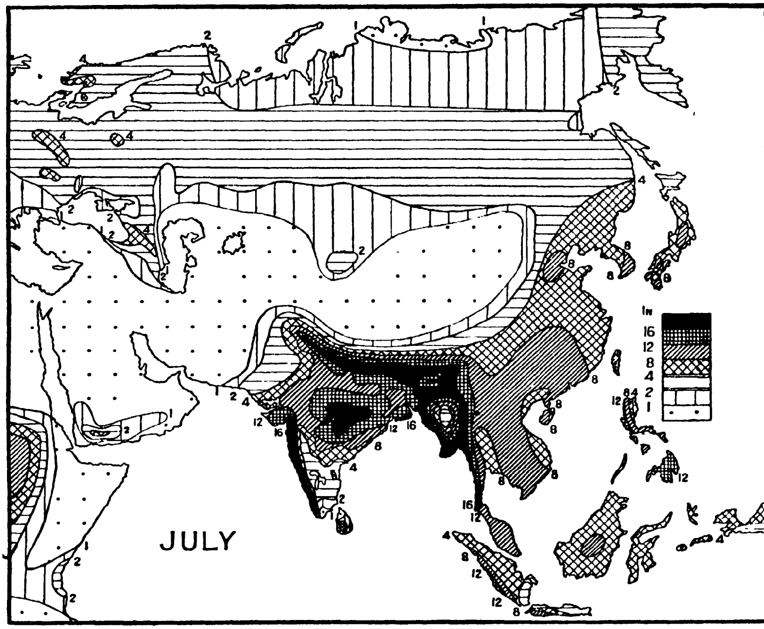


FIG. 46. Mean precipitation, July (Herbertson).

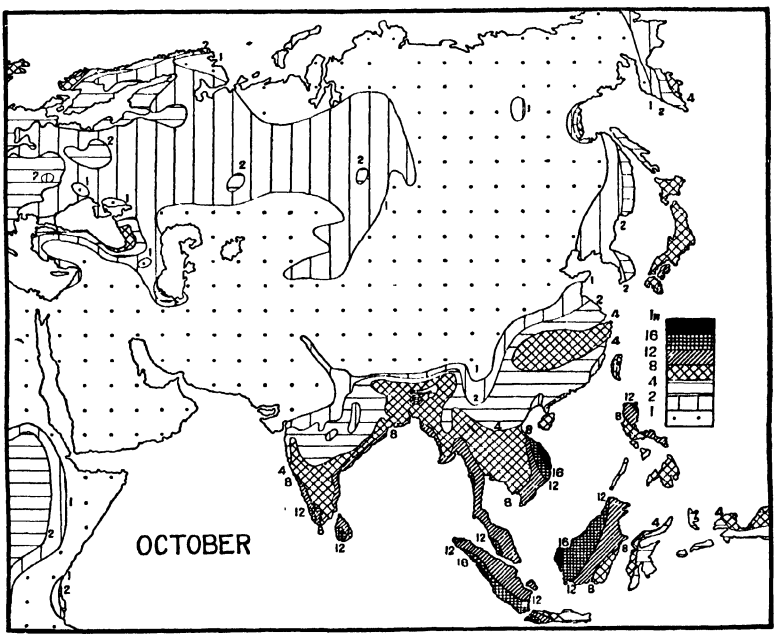


FIG. 47. Mean precipitation, October (Herbertson).

OCEANIC CONDITIONS

Some features of the Indian Ocean are described on pages 30, 31. The east coast of Asia is washed by the waters of the North Equatorial Current of the Pacific. In summer the current is deflected north past the Philippines, and off Formosa joins the stream which has gone north-east from the Java Sea and up the China Sea under the influence of the summer monsoon. The combined waters form the Kuro siwo which goes north-east on both sides of Japan, and then east across the North Pacific towards North America. The water is very warm, the surface temperature being about 82° from Singapore to the south of Japan. But off Japan it falls rapidly, to 70° off Hakodate and 60° off the south of Sakhalin; in the Sea of Okhotsk it is about 50° and on the shores of Bering Strait only 40°.

In winter the North Equatorial Current strikes the Philippines and is deflected north as in summer towards Japan; the surface temperature round the Philippines is about 79°, off the south of Japan 60°. But a cold inshore current goes south off the China and Indo-China coast, driven by the strong NE. monsoon; an abrupt fall in temperature marks its outer edge. In February the surface of the sea on the east of Formosa is about 70°, off the China coast in the same latitude only 60°. In the Yellow Sea it is below 50°, and it falls to 32° in the Gulf of Chihli. In the Sea of Japan the range is from about 50° in the south to below 32° off Vladivostok. The Sea of Okhotsk and the Bering Sea have surface temperatures well below 32° and are largely ice-covered; the cold water flows south past the Kurile Islands, along the east of Hokkaido, and to about lat. 38° N. on the east of Honshu; the west of Honshu has warmer water in the western branch of the Kuro siwo which finds its way through Tsushima Strait and along the Japanese coast of the Sea of Japan.

CHAPTER XIX

THE INDIAN REGION (INDIA AND PAKISTAN). BURMA. CEYLON

(The *Climatological Atlas of India*, published for the Government of India, should be consulted by the reader.)

A REGION which is so vast in size and diverse in surface as India must needs have great variety of climate. But a certain unity results from the monsoonal changes which are common to the whole, and description can best be based on the seasonal rhythm, following the main features of the climates month by month.

The year is popularly divided into three seasons, the cold season from October to March, the hot season from March to June, and the rains from June to October, but a more convenient division for the present purpose is that adopted by the former Government Meteorological Department:

(*a*) The season of the NE. monsoon:
- (i) January and February, cold-weather season.
- (ii) March to mid-June, hot-weather season.

(*b*) The season of the SW. monsoon:
- (i) Mid-June to mid-September, season of general rains.
- (ii) Mid-September to December, season of retreating monsoon.

COLD-WEATHER SEASON

Central Asia is the seat of very high atmospheric pressure, with a steep gradient on the south for north-easterly winds (Fig. 41), and the pressure-gradient and circulation over the Indian region might appear at first sight to be part of the same system. But various considerations suggest that they are separate, and belong to the sub-tropical anticyclonic cell which extends from the west with its axis near the base of the Peninsula. The lofty ranges and plateaux north of the Plains separate the surface circulations of the Indian region and central Asia effectively. The anticyclonic cell of India (which is of no great intensity) gives light north-westerlies on

the surface in the Plains, north-easterlies in the north-east of the Peninsula, Assam, and Burma, and easterlies in the south where they merge with the NE. monsoon of south-east Asia; this circulation persists, with stronger winds, up to about

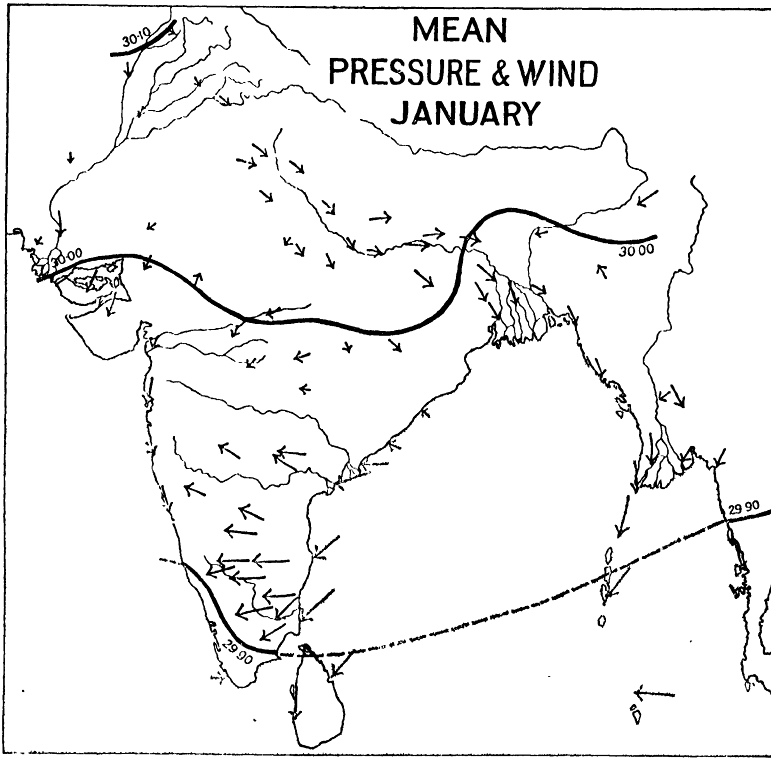


Fig. 48. Mean isobars and winds. (*Climat. Atlas of India.*)

8,000 feet. The high plateau of Tibet on the north is swept by westerlies, forming perhaps part of the inflow in the higher atmosphere which feeds the cold anticyclone of central Asia.

The winds in the Plains are very light, averaging only 2 or 3 miles an hour, and this may partly explain the fact that windmills are not used by the natives. The air-movement is more rapid in the south, but the wind cannot be described as strong.

The goal of the NE. winds of the winter monsoon is the equatorial trough of low pressure, 8° to 10° south of the equa-

tor over the Indian Ocean. Still farther south are the sub-tropical high-pressures of the south hemisphere, from which the SE. trade blows to the same trough, where it converges with the NE. monsoon.

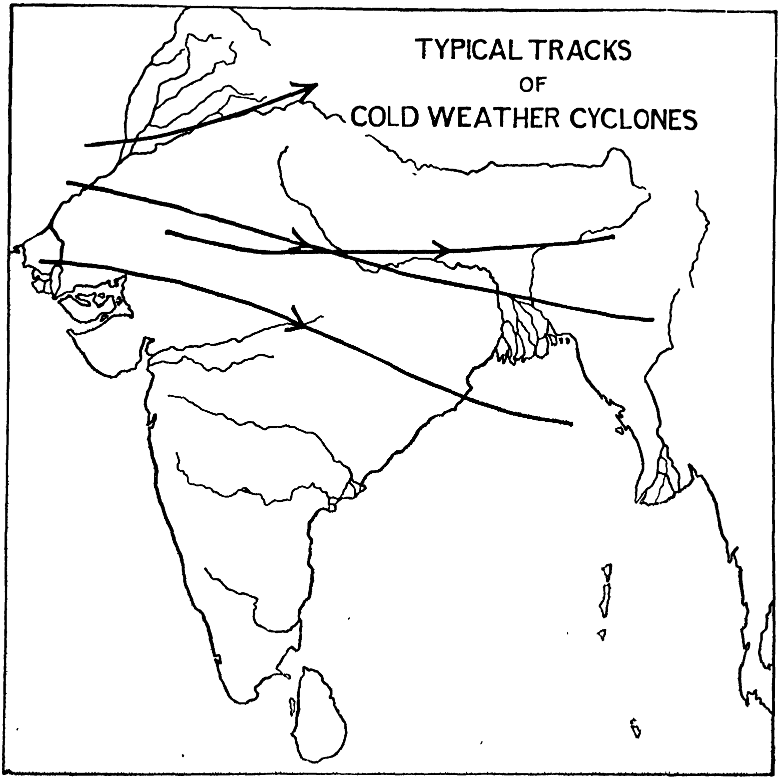


FIG. 49. Generalized tracks of winter disturbances.

January is a beautifully fine month in most of the region. The offshore winds give little or no rain. The sky is remarkably clear; hardly anywhere does the cloud exceed 2 tenths and in the west of the Deccan and in Burma it is less than 1 tenth. Thus during the cold-weather season the climate is almost as sunny as anywhere on the earth. The cloudiest areas are the north-west and the extreme south, but even there the sky is far clearer than in England, and the visibility is extremely good except in the rainy spells now to be described.

The clouds and rain of the north-west accompany the dis-

turbances which are an important interruption of the generally fine weather. At intervals from the end of October till June these shallow depressions, 'western disturbances', ad-

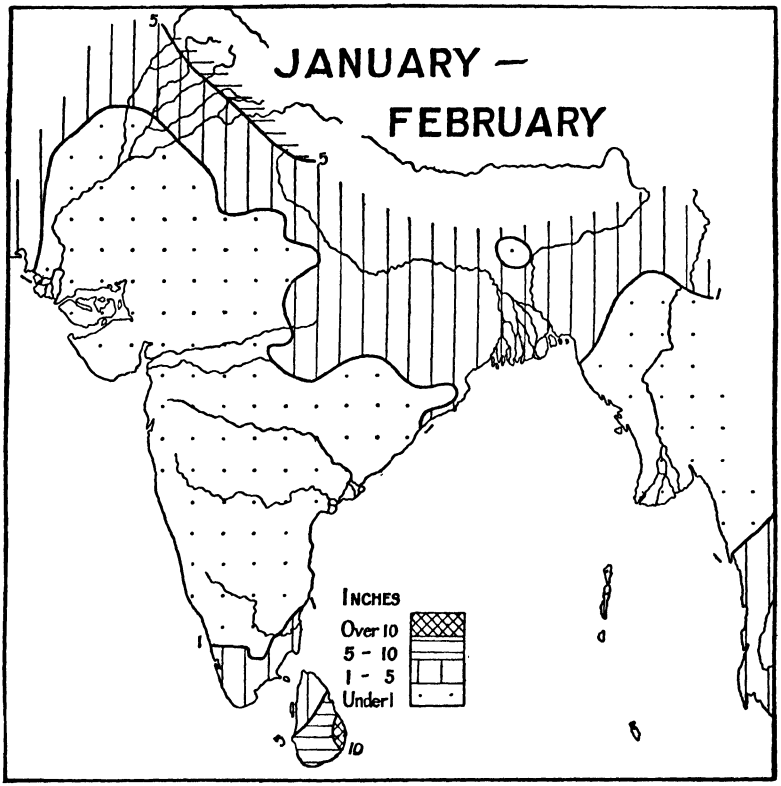


FIG. 50. Mean precipitation, cold-weather season. (*Climat. Atlas of India.*)

vance from the west, over Persia and Afghanistan into Pakistan (Fig. 49). Their average numbers, according to official data, are:

Nov. .	. 2	Jan. .	. 5	Mar. .	. 5	May .	. 2
Dec. .	. 4	Feb. .	. 5	Apr. .	. 5		

The belt they follow is the zone, favourable for frontogenesis, between the cold anticyclone of central Asia and the warm sub-tropical anticyclone on the south. Many of them come from the Mediterranean. In the early and late months their tracks are over the north of Afghanistan and the western

Himalayas and Karakoram, but from December to April they come farther south and influence the Punjab, Rajputana, Sind, and less prominently the Ganges plain as far as Patna. In the Vale of Peshawar they give considerable rain in January, February, March, and April, most in March. In Kashmir the maximum is in April, but March has almost as much. In November and December they may give cloud without much rain. In March and April, with the increasing heat of the sun,

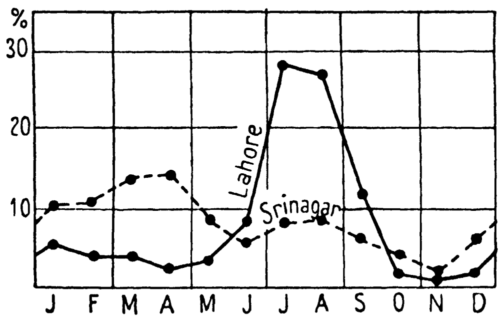


FIG. 51. Mean monthly precipitation, percentage of annual total.

a local convectional effect is added, and thunderstorms, hailstorms—the hailstones being sometimes very large—and occasionally tornadoes mark their passage. They are important in that they provide an appreciable rainfall (from 0·5 to 2 inches in January, nearly as much as that of an English January) on which the winter crops of wheat and barley in the north depend (Fig. 50). The rain is heaviest on the north-west frontier and in the Punjab; the Ganges plain benefits occasionally, but most storms die out before they can reach Bengal. The inner valleys of the Himalayas (Srinagar, Fig. 51) and probably all the highest parts of the chain derive much of their deep annual snowfall from them. In the Vale as well as on the mountains of Kashmir most of the winter precipitation is snow, and the North-West Frontier Province occasionally has snow down to 1,000 feet. At Peshawar (Fig. 66) and in Afghanistan the winter precipitation exceeds the summer; even the arid Khyber Pass has 12 days with precipitation in March and in April. But in the Punjab and farther east the mean precipitation shows merely a small secondary maximum in the early months of the year, which is far surpassed by the summer

maximum (Lahore, Fig. 51). A failure in the winter rains causes considerable distress among the agricultural population.

Ceylon and the extreme south of the Peninsula provide another exception to the fine dry weather of most of the Indian region, being less than 10° from the equator and liable

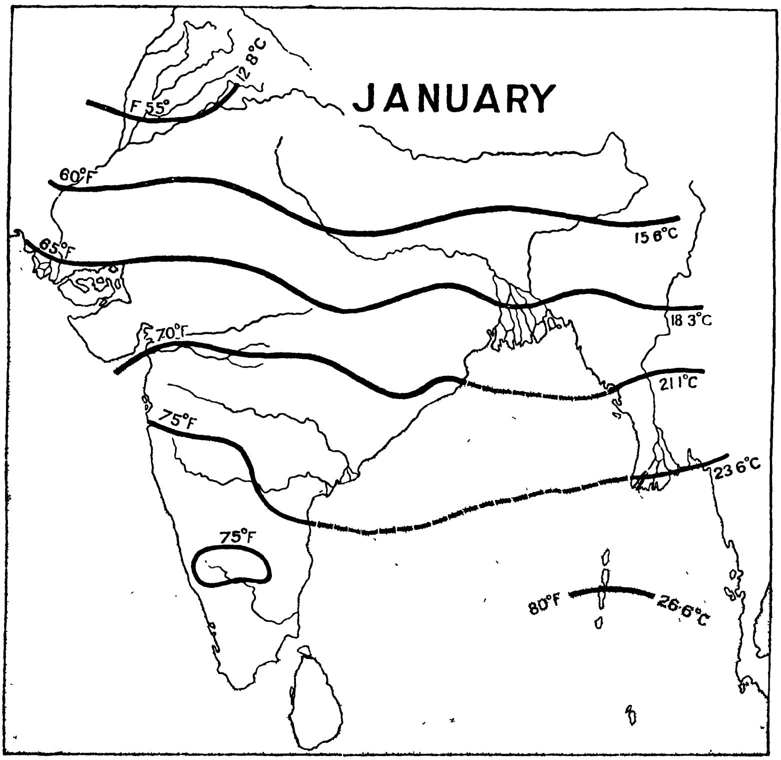


FIG. 52. Mean isotherms.
(*Climatological Atlas of India.*)

to be influenced by temporary northward migrations of the equatorial low pressures. The east of Ceylon gets heavy rains, associated with the NE. monsoon, which has crossed the warm waters of the south of the Bay of Bengal and rises over the mountains of the island. The east coast has over 12 inches in December, 5 in January.

The temperature in January (Fig. 52) is comparable with that of Europe in July. On the north-west frontier the mean

is below 55°, at Peshawar 50°; in the Plains, north and central Burma, and the north of the Peninsula from 55° to 70°, as in north and central Europe; and in the middle and south of the Peninsula, Ceylon, and south Burma, from 70° to 80° as in Spain, Italy, and Greece.

In the north Europeans find the weather very pleasant:

> In his consciousness of awakened energy the expatriated European feels that it also is the cold season, refreshing and invigorating, and affording a climate than which Italy itself can offer nothing more delightful. The thinly-clad native, inured to heat, and living in a draughty hut, with perhaps a single meal a day of not very stimulating food, is less enraptured with the delights of the cold weather. In the early morning his limbs are benumbed and his faculties torpid, and he swathes his head and mouth in a fold of his body cloth, and cowers over the embers of his little fire, till the warmth of the ascending sun restores him for some hours to his state of normal activity (BLANFORD).

The daily range of temperature is larger than in Europe, the January mean being about 30° in the Punjab. The days in the north-west are usually not much warmer than in England in July, but the nights are considerably colder, and frost is frequent; Peshawar has recorded temperatures below 25° and enjoys dry bracing weather. In Rajputana frost is rare, in Bengal and Assam unknown, and the air is much less bracing owing to the abundant moisture; the lowest record at Delhi is 33°; at night fog often covers the low plains. On the coasts temperature is more uniform as well as higher than in the north-west, the mean daily range being about 20°. In Ceylon, the hottest district in this season, the thermometer rarely falls below 70° or rises above 85°, and, compared with that of the north of India, the air is damp with a mean relative humidity of 70 per cent. But the west of the island is much drier in January than in the rest of the year, and the dryness is the disagreeable feature of the January weather.

February brings little change. Pressure and winds remain much the same, except on the west coast of the Peninsula where the winds are now westerly and north-westerly. Depressions continue to appear in the north-west, and in some districts give more rain than in January.

HOT-WEATHER SEASON

In March with the northward movement of the sun temperature rises rapidly, especially in the interior of the Deccan atmospheric pressure falls in sympathy over the heated land

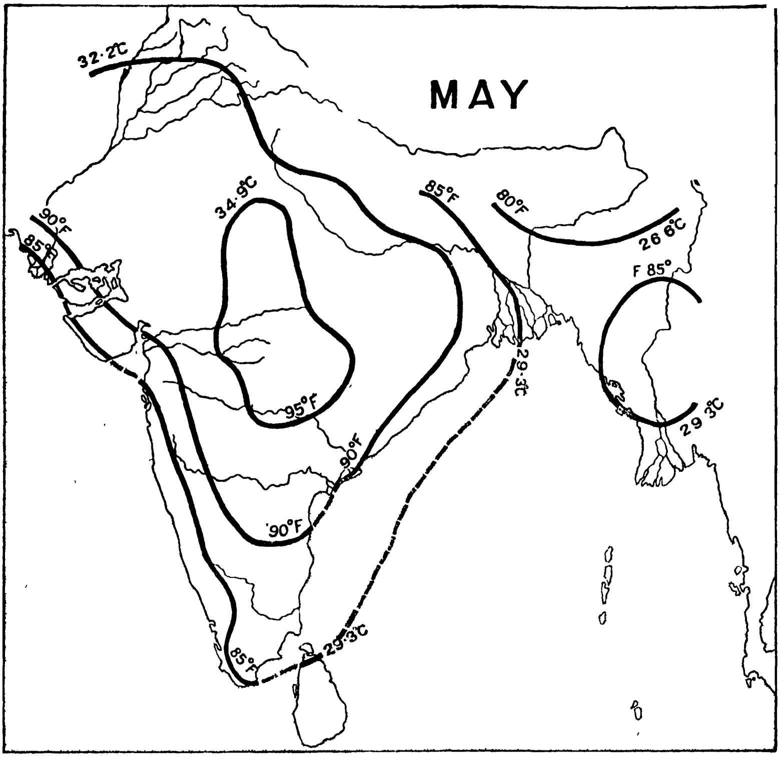


FIG. 53. Mean isotherms.
(*Climatological Atlas of India.*)

but the sub-tropical anticyclonic cell (p. 155) persists. The wind is still north-west over the Plains, but on the coasts the sea-breezes get stronger, from the north-west on the west coast of the Peninsula and from the south on the east coast and in Bengal, and bring moist air, and a little rain to the south of India and Ceylon and to Bengal and Assam, but the rest of the region is unaffected, and the relative humidity falls with the rising temperature.

In April and May the sun is almost overhead, and the days

become hotter and hotter (Fig. 53). The north of India is hottest with its dry air and cloudless skies. In central India the mean temperature is above 85° in April, 95° in May. On an average day in May the thermometer will exceed 105° in the United Provinces, and occasional readings up to 120° must be expected. Sind is still hotter (127° has been recorded), and Jacobabad, near the Thar desert, is one of the hottest stations. The diurnal range is large, over 25°, but even a drop

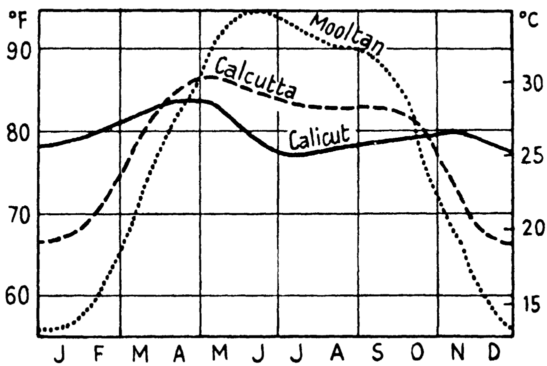


FIG. 54. Mean temperatures.

of 30° from such furnace-heat at midday leaves the night temperature 75° to 80°, high for a July afternoon in England. Few parts of the world are hotter. Work must be suspended in the midday hours, and any activity out of doors is impossible as long as the sun is above the horizon. It is advisable to take precautions against the sun, for the heat and the glare, both direct and reflected, are intense. A good description of the weather at this time by a resident is given later (p. 187). The air is very dry indeed, humidities as low as 1 per cent. being sometimes recorded; all vegetation is burnt up, not a green thing is to be seen. The sky is almost cloudless, but it cannot be described as blue owing to the constant dust-haze, a greyish pall through which the sun shines as a pale disk. There is no rain at all.

The south of India is far cooler. Ceylon and the west coast of the Peninsula have a mean temperature in April and May between 82° and 85°, and at midday 100° is not likely to be exceeded. But though the days are cooler the nights are

warmer than in the north, the diurnal range of temperature being below 15°. Moreover, the air is moist and the rainfall considerable, especially in western Ceylon. Thus the south is much warmer than the north and the Plains in the cold season but

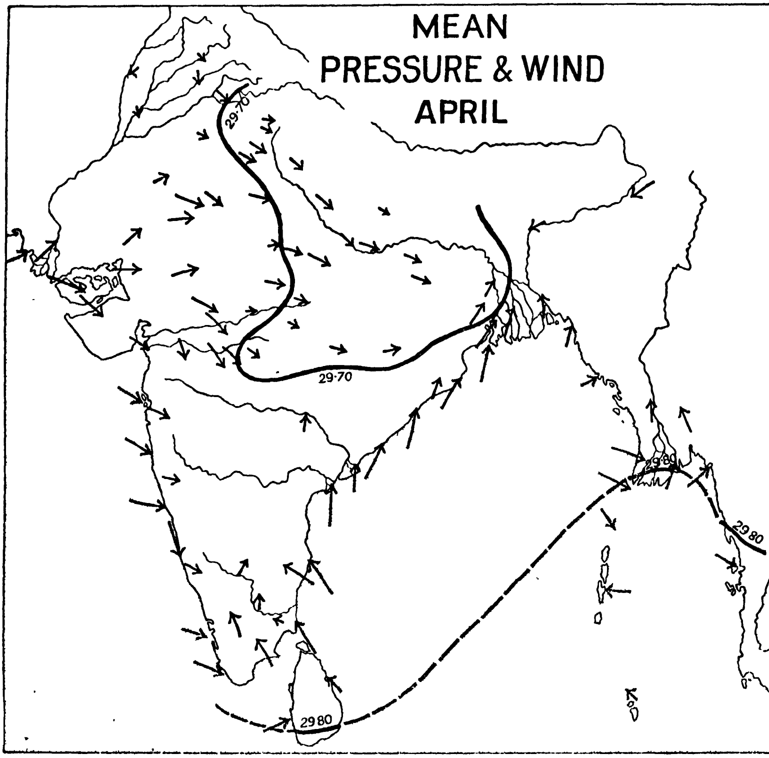


FIG. 55. Mean isobars and winds.
(*Climatological Atlas of India.*)

considerably cooler in the hot; both the annual and the diurnal range is much less in the south (Fig. 54).

With the increasing heat pressure over India decreases. By April (Fig. 55) a definite low-pressure system has formed over the land, with feeble gradients which are considerably steepened in May; indeed, in May the gradient is almost as steep as when the SW. monsoon is at its height. A similar system, possibly deeper and developed earlier but adequate instrumental observations are lacking, forms over the south

of Arabia. The wind is onshore round the coasts, bringing considerable humidity. In the south-west of the Peninsula and in the middle and west of Ceylon the mean rainfall (Fig. 56) exceeds 5 inches in April and 10 inches in May, the

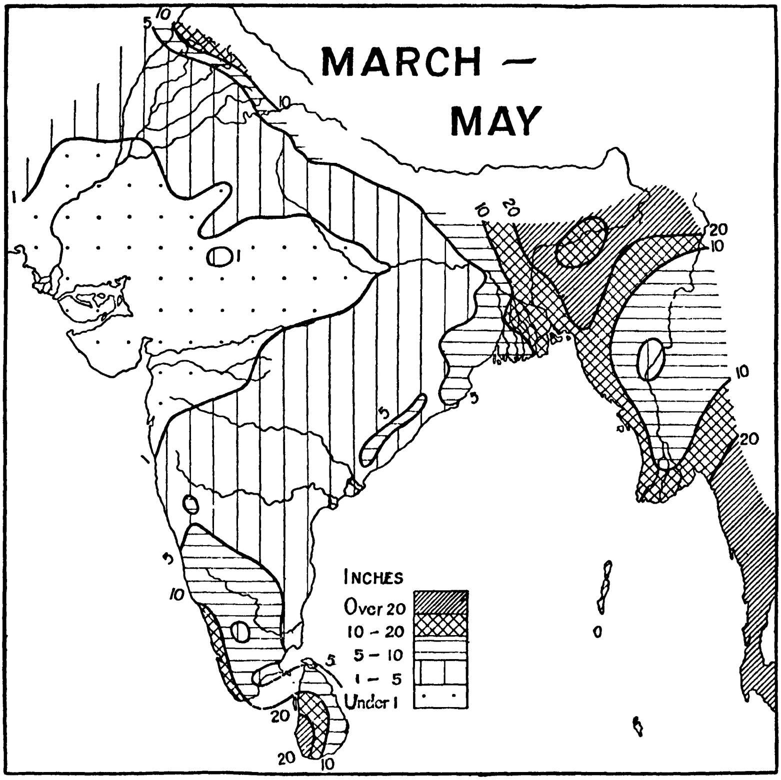


FIG. 56. Mean precipitation, hot-weather season.
(*Climatological Atlas of India.*)

'mango-showers' of south India; the west of Ceylon, however, has an equatorial rather than a monsoonal régime, with two major rains April–June and September–November; each has about 30 inches of rain at Colombo. Assam and Burma also have considerable rainfall and damp air, sultry, hot, and unpleasant, but with these exceptions the hot season is one of intense heat and fine, dry, almost rainless weather. The heat, it is true, has already caused a definite low-pressure system to develop, and the winds on the coasts are onshore. But the

summer monsoon has not yet started, and the season may be regarded as one of preparation for its arrival.

The hot season is not exempt from disturbances, the last manifestations of the winter depressions. In the dry northwest they may take the form of strong squalls of short duration, with very thick dust-clouds, so thick that it is sometimes dark at midday; the visibility is usually poor in this season, and especially so at these times. The squalls occur during the heat of the day, and effect a welcome cooling of the air, though no rain reaches the ground; they are most frequent in May and June, on the average one a week. Similar squalls are known throughout the Plains, but nearer the sea the prevailing onshore winds contain much vapour, and the squalls, known here as 'nor'-westers', generally take the form of thunderstorms with sharp showers of rain and large hailstones. Most of the April and May rainfall of Bengal, Assam, and Burma is of this kind; in Assam it is of great value for the tea crop. The immediate cause of the squalls is probably the existence of a dry, cool, NW. current above the hot moist wind from the sea, so that convectional overturning results. The same regions are visited occasionally by tornadoes or whirlwinds of small diameter, usually a few hundred yards, and trees and buildings may suffer serious damage, and even heavy objects may be carried some distance.

On the adjoining seas the pressure gradient is slight, and the winds are weak and variable. These conditions are favourable to the development of tropical cyclones, mostly in the south of the Bay of Bengal (p. 182).

Season of General Rains

In the beginning of June the features of the hot season just described are intensified, and the heat and drought become unbearable in the Plains. But early in the month heavy cumulus clouds are seen moving from the east with much lightning, and dissolving in the evening to leave the night sky bright again; the SW. monsoon sets in, or, to use the word which well expresses the phenomenon, 'bursts'. It is a change not so much in the direction of the wind as in its force and in the whole face of the weather with the arrival of the new air-mass. The monsoon, led in by its boisterous front,

blows strongly from south-west, very strongly at sea, particularly in the west and middle of the Arabian Sea where its mean velocity continues at 25 to 30 miles an hour through July and August. The air is saturated with vapour, and thick masses of cloud cover the sky and give heavy rain and thunder. These stormy conditions last for a week or more, the forerunner of the weather which will continue for three months, generally very moist and rainy but with breaks. The clouds shade the land from the sun and the streaming rains cool the air so that temperature falls at once (Fig. 54), and the mean daily range decreases, from nearly 30° (inland) in May to less than 15° in July. Living things have a feeling of relief, the parched land drinks and is luxuriantly green again.

The movements of the air-masses and the magnitude of the processes involved are realized if it is remembered that the monsoon originates in the South Indian Ocean as the SE. trade and reaches India after a passage of 5,000 miles over tropical seas. In January the equatorial trough, with its intertropical convergence, the limit of the SE. trade, was about 10° south of the equator; swinging north with the sun, in March it is near the equator and in May reaches Ceylon and the Nicobar Islands; its advance is slow but certain despite minor oscillations, now slowing down, now surging forward again. The SE. trade, obeying the gradient, becomes a SW. wind, the SW. monsoon, after crossing the equator into the north hemisphere behind the trough, and the character of the air is modified from maritime tropical to equatorial. In May the trough, with the monsoon behind it, moves north over the Peninsula, reaching Bombay in early June and its most northerly position soon after. The intertropical front is then off the Makran coast, crosses into Pakistan near Karachi, and extends eastward down the Plains into the north of Burma and Yunnan. Its remarkably long northward advance is a result of the breaking-down of the normal sub-tropical high surface pressures of the North Indian Ocean and north India by the intense heating of the land described on page 164, and weakening of the northerly winds. Simultaneously with the decrease of the high pressures in the north Indian region the sub-tropical high pressures in the South Indian Ocean are intensified (Fig. 57), the pressure-gradient from south to

north is greatly strengthened, and the SW. monsoon surges forward as a very massive current of equatorial air behind the intertropical front; the arrival of the front is the anxiously awaited 'burst' of the monsoon, the abrupt change already described from stifling dry heat to skies overcast with thick driving clouds and torrents of rain. The monsoon differs entirely in origin and character from the sea-breezes which had blown previously, on some coasts from the same direction.

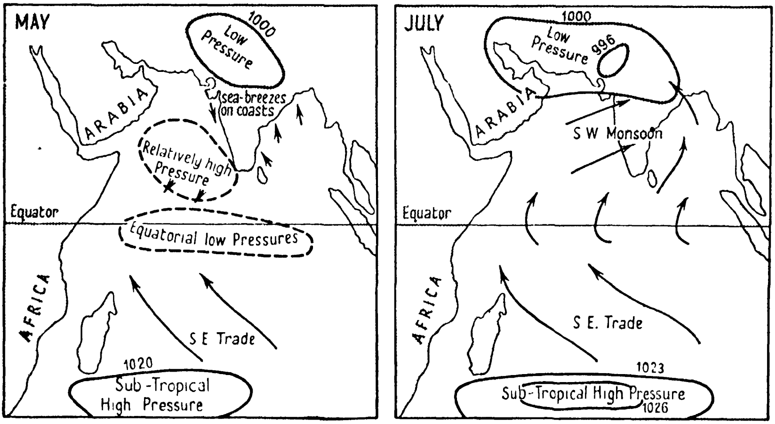


FIG. 57. Generalized distribution of pressure before (May) and after (July) the arrival of the monsoon.

Behind the intertropical front the warm moist air of the monsoon dominates the weather, which continues damp, cloudy, and rainy, but with less intensity than at the burst.

On the west coast of the Peninsula and the coast of Bengal June and September have more thunder than the rest of the year, associated with the frontal activity of the arrival and the retreat of the monsoon. But in the Plains convection in the humid monsoonal air itself makes July and August the thundery months. The far north-west has but little thunder, and most of it is in April under the combined influence of the winter disturbances and rising temperature, and in August:

MEAN NUMBER OF DAYS ON WHICH THUNDER OR LIGHTNING IS RECORDED

	J.	*F.*	*M.*	*A.*	*M.*	*J.*	*J.*	*A.*	*S.*	*O.*	*N.*	*D.*	*Year*
Bombay .	0	0	0·2	0·7	1·7	**4·7**	2·0	*0·2*	**4·8**	2·8	0·3	0	17
Calcutta .	0·1	0·8	3·5	6·9	6·9	**7·6**	*5·6*	5·8	**9·4**	3·6	0·2	*0*	50
Allahabad .	0·8	1·7	1·1	0·7	1·6	3·8	7·8	**8·3**	4·8	1·2	*0*	0·2	32
Peshawar .	0·1	0	0·4	**1·6**	1·1	1·2	*0·4*	**1·1**	0·9	0·7	0	0	7

The SW. monsoon blows in a fairly steady current more than twice as strong as the NE., and it is saturated with vapour from its long passage over the intertropical ocean. At Bombay its average velocity is about 14 miles an hour, but this is more than in most of the region. It is still stronger at sea, especially in the Arabian Sea, owing probably to the

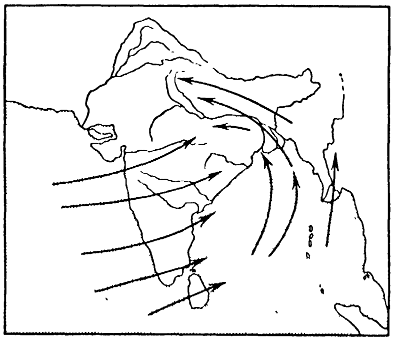


FIG. 58. Main currents of the monsoon.

influence of the low-pressures of south Arabia. Reaching the west coast of the Peninsula, it surges on towards the east and north, and arrives with remarkable punctuality in most years:

	Mean date	
	Onset	*Ending*
Bombay	5 June	15 Oct.
Bengal	15 June	15–30 Oct.
NW. Province	25 June	30 Sept.
Punjab	1 July	14–21 Sept.

By July all the Indian region is under its influence.

Up to 10,000 feet the monsoonal inflow changes little in direction and, on the whole, not much in velocity, except in the north-west, particularly in Sind.

The two main air-currents of the monsoon are shown in Fig. 58, one meeting the Western Ghats at right angles, the other advancing over the Bay of Bengal, and turning north-west up the Ganges plain. The latter has picked up additional heat and vapour over the Peninsula and the Bay, and possibly this is one factor in the frontal interaction with the former in the long trough of low pressure which extends south-east from the centre over Sind; at any rate Central India gets

heavy rains. The main air-stream is south-easterly in the plain below Allahabad, but the winds are more variable, often westerly, beyond. No doubt the great wall of the Himalayas plays an important part in directing the SE. winds of the Plains, and through them in controlling the north limit, and the force, of the Arabian Sea branch of the monsoon. It may be noted also that the barrier, by largely preventing the inflow of air from the dry interior of Asia, makes that from the Indian Ocean specially strong. Throughout south and east Asia the summer monsoon arrives charged with vapour from the warm seas over which it comes. China also has heavy summer rains, but the rain is heavier over the Indian region owing to the favourable arrangement of the mountain-ranges which bound the country. Sir G. C. Simpson (*Q.J.R. Met. Soc.*, 1921) lays stress on this feature. The region may be regarded as a compartment with mountain sides 6,000 feet or more high on the east, north, and west, but open on the south to receive the powerful inrush of the moist ocean winds. The air that enters must rise at least 6,000 feet, most of it higher, and the cooling that results is a major cause of the heavy rainfall, the local distribution being determined by the position of the ranges in relation to the wind directions (but the scanty totals of the mountainous edge of Afghanistan and Baluchistan are to be noted).

The monsoon is the rain-giver of the sub-continent and the source of livelihood for its millions of people; 85 per cent. of the rainfall is derived from it. But the rain is not continuous; breaks may be lengthy and the total fall reduced so much that crops fail and famine follows (p. 183). Most of the rain falls in depressions, on the average 3 or 4 in each month, comparable with those of the cold season in the north-west but travelling in the opposite direction. They develop over the head of the Bay of Bengal on the intertropical front when it oscillates south (Fig. 66), and advance in the trough of low pressure up the Plains, maintaining their cyclonic characteristics as far as Rajputana and occasionally into Baluchistan; the rain falls in tropical downpours, the districts favoured depending on the track followed by the depression. Shallow thermal depressions are another source of heavy, but more local, rain. Thunderstorms are rare, in striking contrast to the

conditions of the previous 3 months when nor'-westers with much thunder and lightning were frequent. In the north-west, including the Vale of Peshawar, the rain is comparatively

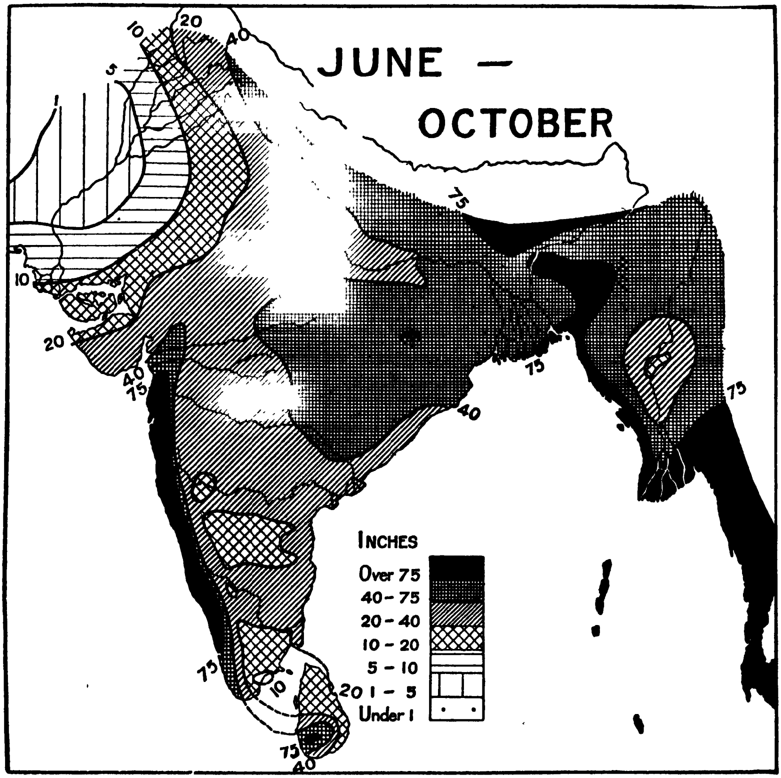


FIG. 59. Mean precipitation, season of general rains. (*Climat. Atlas of India.*)

light, but sometimes depressions give 2 or 3 days of heavy rain and thunder.

The map of mean rainfall (Fig. 59) shows clearly the influence of the relief. The totals in the following paragraphs, unless otherwise stated, are means for the months June, July, August, September—the monsoonal rains. The west coast of the Peninsula, and still more the Western Ghats, the Arakan Yoma, and the interior of Ceylon, have enormous totals, 50 to 100 inches on the coast, rising to 350 inches on the windward slopes of the hills. The cloud-masses billow up to 30,000

feet and more with strong up-draughts, a formidable obstacle for aircraft. But the heavy rainfall of the west of the Peninsula does not extend far north of Bombay; the Indus delta is arid—Karachi has only 8 inches, while Bombay has 67 inches.[1] East of the Ghats the decrease is extraordinarily rapid; less than 100 miles from the coast the rainfall has diminished from over 300 inches to about 20. Series illustrating the rain-shadow are:

Station	*Position*	*Mean rainfall in inches, June–Sept.*	*Number of rain-days,* June–Sept.*
Mangalore . .	West coast of Peninsula	109	67
Bangalore . .	Interior of Peninsula	19	33
Madras . . .	East coast of Peninsula	15	26
Kandy . . .	Highlands of Ceylon	29	79
Trincomalee . .	East coast of Ceylon	10	22

* With at least 0·1 inch of rain.

Most of the middle and east of the Deccan has between 15 and 30 inches, but the Palghat Gap gives entry to heavy rains.

Similarly on the east of the Bay of Bengal the transition is remarkably abrupt from the excessively rainy coast and windward slopes of the ranges of Tennasserim and Arakan to the dry interior of Burma with less than 30 inches (the rainiest months are May and September, separated by an appreciably drier July). In the north the Arakan ranges join the Khasi Hills, and here is the heaviest rainfall, not only of the Indian region, but of the whole world; the configuration of the district, therefore, merits study. The Khasi Hills are an east–west range, 150 miles long, with an altitude of about 5,000 feet. In the east they meet the northward continuation of the Arakan ranges, trending north-east with a similar altitude, and a wide depression opens to the south-west between the two systems. Part of the Bay of Bengal branch of the monsoon enters the funnel-shaped depression facing it, and the air is forced vigorously upward as the passage narrows. The result is a phenomenal rainfall, which reaches its maximum, so far as records exist, at Cherrapunji. This station is about 200 miles from the bay, but the intervening tract consists of low-lying land, practically a vast lake at this time owing to the rivers having overflowed their banks. The flood water is

[1] Bombay has had 28 inches in 24 hours (in September 1949).

warmer than the sea, and the air-currents which have blown over it before they reach Cherrapunji contain an enormous mass of vapour. Dacca, just outside the mouth of the funnel, has a mean rainfall in the monsoon months of 49 inches; Sylhet, in the narrower part of the funnel but still on low ground, has 106 inches, Cherrapunji at an altitude of 4,309 feet, on the south side of the Khasi Hills abóve Sylhet, 310 inches. Beyond the ridge the rainfall decreases rapidly; Shillong, only 25 miles from Cherrapunji, and at a greater altitude but on the northern leeward slope, has only 55 inches, about one-sixth as much as Cherrapunji, and Gauhati, still farther north in the bottom of the Brahmaputra valley, only 43 inches. At Cherrapunji 905 inches once fell in a year (annual mean 428 inches), and 41 inches, twice the mean for the whole year in the east of England, has fallen in a single day.

Bengal and Assam have more rain than the rest of India with the exception of the west coasts. The amount is greater in the east than in the west, in the south than in the north. Extremely heavy downpours are not unusual; Purnea, north of the Ganges in Bihar, has had 35 inches in a day. Owing to the moist air and frequent thunderstorms of the hot season that precedes it the burst of the monsoon is not nearly so marked as on the west coast.

In the Plains the rainfall decreases with increasing distance from the Bay. The following series illustrates the diminution from Bengal to Sind:

Mean Rainfall and Number of Rain-days, June–Sept.

Calcutta	45 inches	63 days
Patna	42 ,,	45 ,,
Allahabad	34 ,,	41 ,,
Agra	24 ,,	31 ,,
Delhi	23 ,,	27 ,,
Mooltan	5 ,,	15 ,,
Jacobabad	3 ,,	13 ,,

The decrease is most rapid beyond the Ganges–Indus divide west of Delhi towards the Punjab, making the deserts of Sind the most arid part of the Indian region. It is noticeable that the Thar desert lies almost in the centre of lowest pressures and the scantiness of its rainfall is at first sight surprising and calls for explanation.

It has long been known that not only moist monsoonal surface air which has come up the Plains from the ocean, but also hot and dry continental air, originating in the distant sub-tropical anticyclone of the North Atlantic and then making a long passage over Eurasia, finally over the hot arid plateau of Afghanistan and Baluchistan, and subsiding over

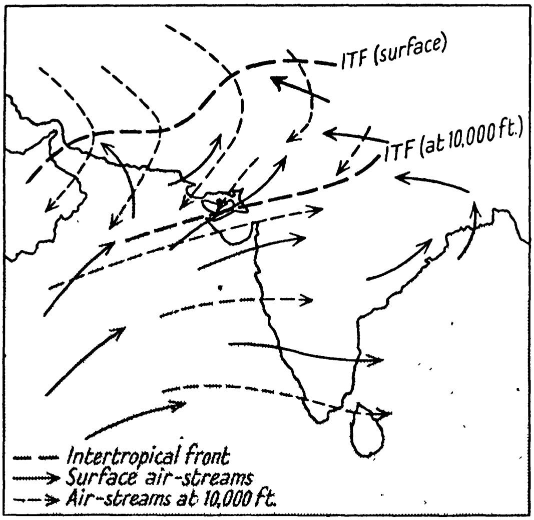


FIG. 60. Intertropical front and streamlines during steady monsoon (based on J. S. Sawyer).

Sind and the Punjab, enter the low-pressure system, the surface layers of the two air-masses meeting in the (surface) intertropical front. The intense heat of the arid lands sets up convection with the usual adiabatic cooling of the rising air, cooling at the dry lapse-rate in the continental air but at the saturated, smaller, rate in the monsoonal air (after condensation of its vapour begins), so that the excess of heat in the former when ascent begins is lost with height, till at about 10,000 feet the monsoonal air is the warmer. The relations between the two air-masses have been investigated in the light of many observations in the surface and upper levels during a period in August which was free from minor cyclonic disturbances by J. S. Sawyer,[1] and his results seem to be in

[1] *Q.J.R. Met. Soc.*, 1947.

large part of general application, though he carefully emphasizes the short period of the observations and points out that the 'static' conditions are probably modified by the frequent monsoonal depressions. The continental air-mass was found to advance farther aloft than on the surface, farthest at a height of about 10,000 feet, so that it projected into the monsoon air, as is shown in Figs. 60 and 61; the intertropical front, or discontinuity, at that level is about 500 miles beyond the surface front.

In its earlier course the monsoonal air, moist and heated by the hot ground, rises with the formation of massive cloud

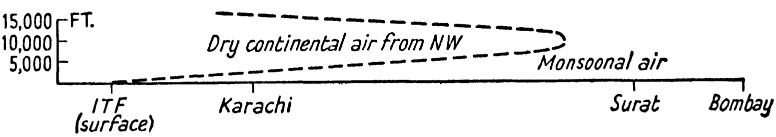


FIG. 61. Continental and monsoonal air over the north-west of the Indian region.

and heavy precipitation, mostly over mountains where no low ceiling is present to check ascent. But in the north-west of the Plains the rising air meets its ceiling at the frontal surface of the projecting continental air, where the ascent is stopped, though 'bubbles' of moist air penetrate into the air above and mix with it, so breaking down the discontinuity to a certain extent. It meets the ceiling first in the neighbourhood of Delhi at about 10,000 feet, and at decreasing heights towards the west as the upper front descends. Mixing with the dry air above prevents further condensation, and precipitation decreases—to nothing save occasional instability downpours in the desert. The rising monsoonal air is carried away with the continental air in its outflow aloft.

If this picture is correct in some degree throughout the summer monsoon it throws light on the rapid decrease of the rainfall on the west from Surat (40 inches) to Karachi (7·5 inches), a decrease which is the more remarkable since the winds are onshore all along this coast and are by no means dry, though less moist than the more oceanic, equatorial, air on the south; the precipitation tends to be proportional to the depth of the air in which ascent occurs, and that depth under the discontinuity decreases rapidly towards the north-west to

beyond Karachi where the intertropical front meets the surface and the oceanic air is excluded.

In the Plains east of Delhi the Himalayas cut off most of the continental air, and the intertropical front can hardly be traced; the frontal interactions that give most rain take place between the monsoonal currents themselves. But, as we have already seen, the general tendency to convergence in all the air entering the Indian region owing to the enclosing mountain-ranges is a large factor in the precipitation.

The arid west, with a mean annual rainfall of less than 10 inches, includes almost all Sind, the west of Rajputana, the south-west of the Punjab, and much of Baluchistan and Afghanistan; the summer rain is in part general, though light, rain associated with rare depressions from the Plains, in part occasional local heavy thunderstorm-rain in the hot hours. Jacobabad, on the Quetta railway west of the Indus, has the lowest recorded means, 3 inches during the monsoon, 4 inches during the whole year. Some years pass with no rain at all, in other years far more than the mean annual amount falls in a few hours in a sudden downpour. The annual mean at Hyderabad, Sind, is 7 inches, but 13 inches fell in 3 consecutive days in August 1865, 10 inches on one of them. Doorbaji, Sind, has had 34 inches in 2 days, the annual mean being about 5 inches. These sudden floods are hardly less fatal to plant-life than the usual drought, for in some places they wash away the soil, and cover it in others with sand, and they also do great damage to property. Most of the rain which goes to make up the small annual mean is of this spasmodic type. The air in the desert is extremely dry, but the coast has a fairly high humidity thanks to the sea-breezes. The sky is cloudless, and the heat extreme (absolute maximum at Jacobabad 126°).

In striking contrast the outer ranges of the Himalayas have exceedingly moist air and very heavy rain, which decreases from east to west as on the Plains:

	Mean rainfall June–Sept.
Darjeeling	102 inches
Naini Tal	81 ,,
Mussooree	89 ,,
Simla	48 ,,
Murree	35 ,,

The clouds hang low, and these hill stations are often enveloped for days and even weeks. They offer no refuge from the ubiquitous rain and moisture of the Plains. The monsoon does not cross the main ranges of the Himalayas; with increasing distance across the outer ranges towards the interior the less is the rainfall. The elevated valleys in the heart of the ranges, such as that of the Indus round Leh, have remarkably

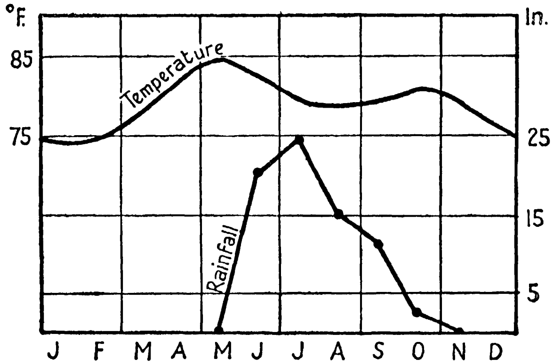


FIG. 62. Mean monthly temperature and rainfall, Bombay.

little, Leh itself only 1 inch during the months June to September:

> In July and August the weather occasionally becomes disturbed owing to the extension of the monsoon current into Kashmir, which causes low cloud and locally heavy rains over the mountains along the Indus valley. Actually there is very little precipitation at Gilgit or Drosh during the monsoon season (VERYARD and ROY).

The rivers roll along in high flood and inundate their low plains for thousands of miles. The floods in the Punjab are especially destructive:

> About July and August comes the rush of life-giving water to the steaming plains; then is the anxious time for the engineer and bridge-maker; then the swelling brown torrent spreads across miles of river-bed, curling and eddying with resistless sweep against piers and abutments, licking the necks of the bridge supports, and bringing down heavy batteries of floating timber and uprooted trees. But in the early dry months of summer these channels are frequently nothing but wide white spaces of glittering sand, with here and there a narrow ribbon of gleaming water permeating the

width of river-bed and offering no difficulty to the passer-by, except where the main channel, narrowed to the dimension of a rivulet, may perchance present an unfordable obstacle.

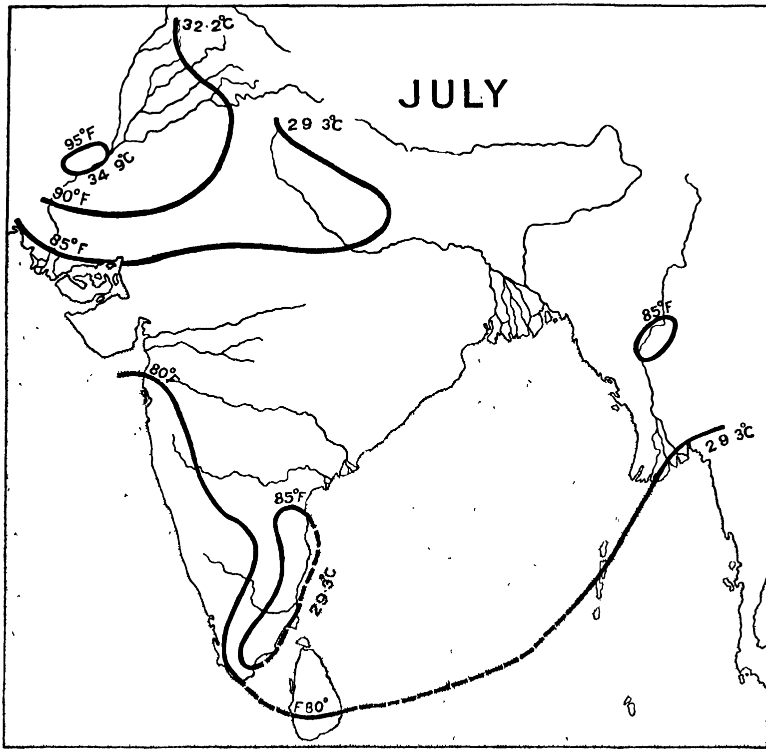


FIG. 63. Mean isotherms.
(*Climatological Atlas of India.*)

An interesting result of the copious condensation of vapour in the massive monsoonal clouds is a marked reduction of the mean lapse-rate of temperature at their level (a reduction, it is true, due in part to other influences):

MEAN LAPSE-RATE OVER THE PLAINS IN JULY (°C.)

Surface–2 km. . .	5·5	4–6 km. . .	5·3	8–10 km. .	6·3
2–4 km. . .	4·2	6–8 km. . .	5·7		

In most of the Indian region the air is cooler during the monsoon (Fig. 62), but the range of temperature from day to night is less than in the hot season. The relief from the heat is

welcome, but the continuous high humidity soon enervates the European. Early in June the United Provinces and the Punjab are among the hottest areas, but towards the end of that month the clouds and rain cool the air. In arid Sind, how-

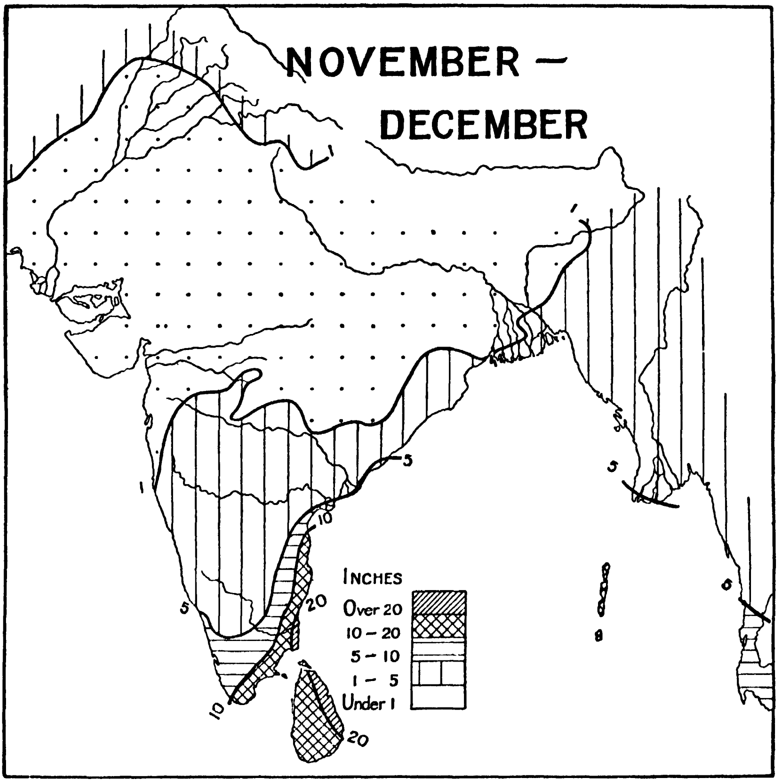


FIG. 64. Mean precipitation during the season of the retreating monsoon. (*Climatological Atlas of India.*)

ever, with little cloud and hardly any rain the temperature in July (Fig. 63) continues about the same as in June, and is by far the highest in all the Indian region. The west coasts of the Peninsula and Ceylon are now the coolest areas, under strong oceanic influence, thick cloud and heavy rain (Fig. 63). In Bengal and Assam the arrival of the monsoon has less effect on the temperature since the previous months are not rainless. On most of the coasts the lower temperature and the

smaller diurnal range, together with the strength of the monsoon, check the development of land- and sea-breezes.

In a normal year the SW. monsoon continues till the middle of September. Then, as a result of the falling temperature,

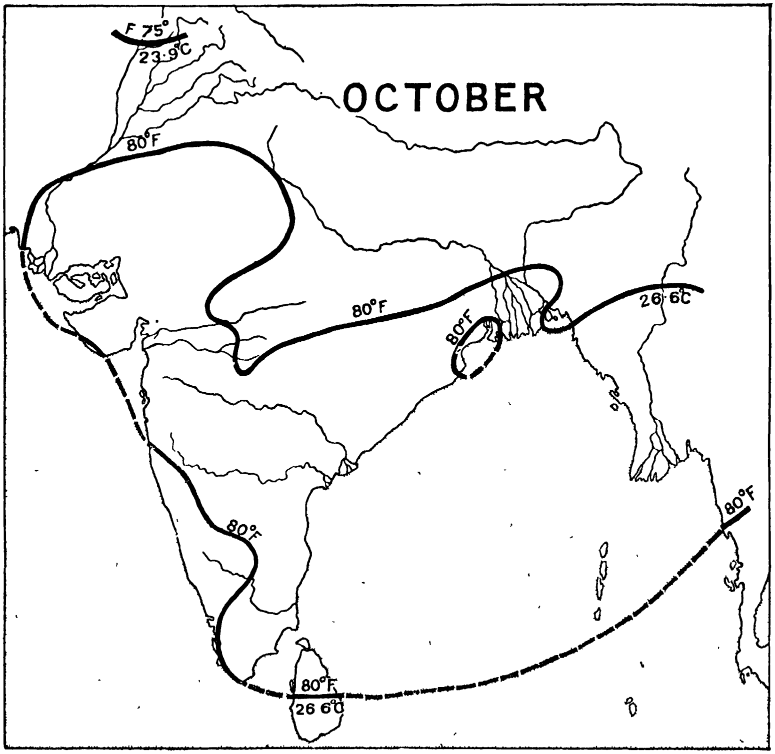


FIG. 65. Mean isotherms.
(*Climatological Atlas of India.*)

the atmospheric pressure increases in the north of the Plains, and the monsoonal currents begin to lose strength and are no longer able to reach the north-west frontier. The weakening is a gradual process, in contrast to the suddenness with which the monsoon started. By the middle of September the monsoon leaves the Punjab, and by the end of the month it fails to reach the United Provinces. NW. winds take its place, and in the beginning of October they extend over Bengal. Bombay loses the monsoon in mid-October.

The distribution of pressure remains much the same in

July and August as in June. In September the low-pressure system begins to fill up, and in the beginning of October pressure is fairly uniform, the isobars for that month showing a tendency to high pressure in north India and relatively low over the Bay, but the gradient is weak.

Season of Retreating Monsoon

As the intertropical front and the SW. monsoon retreat the sky clears, the sun shines again, and temperature rises for a

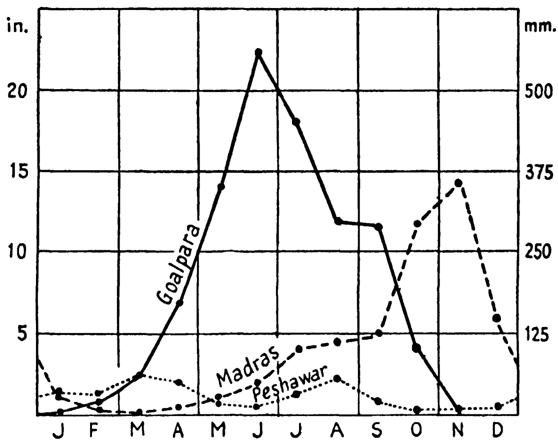


Fig. 66. Mean monthly precipitation.

few weeks before falling to its winter minimum (Figs. 54 and 62); the land is still waterlogged when the heat increases, making this an unhealthy period in some districts, but in the north-west October and November have the best weather of the year, with bright blue skies, clear air, and pleasant temperature.

An exception is found, however, in the south-east of the Peninsula, which gets its heaviest rains in October and November (Fig. 64). They result mainly from frontal interaction in the intertropical convergence between the NE. monsoon now advancing into the Indian Ocean and the retreating south-westerlies. At Madras the mean total is 26 inches in these two months (only 15 inches in the four months June to September). All the east and south-east of the Peninsula south of the Godavari delta has heavy rains in October and

November, and also the east of Ceylon which has much rain till January; in Madras the rains cease by the end of the year, when the intertropical convergence has cleared the area and the NE. monsoon is well established. Part of the rain is associated with tropical cyclones in the Bay.

The temperature over the whole country is remarkably uniform in October (Fig. 65), the mean being about 80° everywhere at sea-level. In November it is becoming cooler in the north and the nights in the far north-west are chilly; in December the cold-weather season starts.

It should be noted that appreciable rain falls in every month of the year in some part of the Indian region. In January and February the north gets rain from the winter depressions (Peshawar, Fig. 66). In March thunderstorms are beginning in Bengal and Assam, and continue to give heavy rain until the monsoon starts in June (Goalpara). The general rains are in full vigour till October, and then during the retreat of the monsoon in November and December Madras has heavy rain.

Tropical Cyclones. One or more of these violent storms usually develop on the intertropical front in May, June, and July during its passage north over the Bay and the Arabian Sea; but when the front has reached the Plains and the monsoon is fully established they are very rare. In September, however, conditions again become favourable as the front returns south and continental air interacts with hot vapour-laden oceanic air in the almost flat field of pressure. The average number of cyclones is 1 or 2 in the earlier, 2 or 3 in the later period; the mean percentage frequency is:

	J.	*F.*	*M.*	*A.*	*M.*	*J.*	*J.*	*A.*	*S.*	*O.*	*N.*	*D.*
In the Bay of Bengal	0	0	2	8	18	5	3	2	8	22	24	8
In the Arabian Sea .	0	0	0	10	20	23	0	0	0	15	26	6

Some usual tracks of cyclones are shown in Fig. 67.

The early storms of the year develop about lat. 10° N. The place of origin moves northward with the sun, till in July it is at the head of the Bay of Bengal, but most of the storms that originate there are not of tropical violence. As the sun returns southward the place of origin of the cyclones follows it, and in November most of them develop south of 12° N. They

usually die out, or at any rate decrease very much in intensity, if they cross any large land-area. But while the centre is still over the sea they can work fearful devastation on the coasts, and Madras, Bengal, and Burma especially have suffered enormous material damage and the loss of thousands of lives.

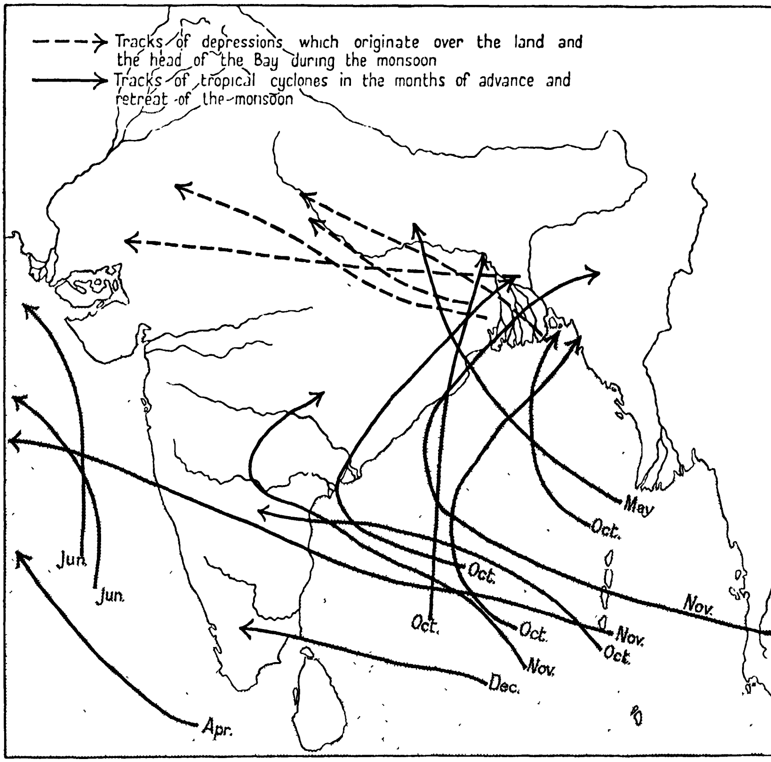


FIG. 67. Generalized tracks of disturbances associated with the monsoon.

Cyclones have been known to cross the Peninsula from the Bay of Bengal to the Arabian Sea, degenerating into feeble storms during their passage over the land, and developing again into hurricanes on reaching the Arabian Sea. Occasionally cyclones from the Arabian Sea reach the Gulf of Oman.

DROUGHTS

The actual rainfall in any year may be either above or below, often very considerably above or below, the mean.

The variability exceeds 100 per cent. of the mean in the west of Pakistan and the drier parts of the Deccan. Deficiencies are of more practical importance than excesses. They may occur during the cold season if the winter depressions of the north are few or feeble, or during the SW. monsoon, which may be late in appearing, early in ending, or give but poor rains owing to frequent long spells of dry weather. The rainfall is most variable in the arid west, in and around the desert of Sind, but here deficiencies are less serious since the crops depend more on irrigation than on rain; least variable in the regions with heaviest mean rainfall, and here again even the greatest deficiencies matter little, since the mean rainfall is more than sufficient for agricultural requirements. They are most serious in the intermediate districts with a mean between 15 and 45 inches and a very dense population. The normal rainfall just about suffices for the crops and any large deficit leads to failure and famine.

The effect on crop-production is greatest and most disastrous in the following areas; (1) Central Burma; (2) The Deccan, including the Bombay and Madras Deccan districts, and Hyderabad; (3) North-west and Central India, more especially the south Punjab, east Rajputana, and the United Provinces (ELIOT).

When a failure in the winter rains is followed by a poor monsoon in the north, or when, as often happens, the summer rains are scanty two years running, the consequences to the natives are, of course, intensified:

A sudden cessation of the rains of 1896 resulted in famine over an area of about 307,000 square miles, with a population of nearly 70,000,000; on the average 2,000,000 persons were relieved daily during the twelve months from October 1896 to September 1897, and the number rose to more than 4,000,000 at the time of greatest distress. . . . In the height of the famine there were for weeks together more than 6,000,000 persons in receipt of relief. On a comparison of the Census figures of 1901 with those of 1891 it is estimated that during these two famine periods the death-roll exceeded the normal mortality of non-famine years by about 5,000,000.

CLIMATIC REGIONS

From the preceding sketch, based on the seasonal changes, it will be seen how manifold are the climates of this vast

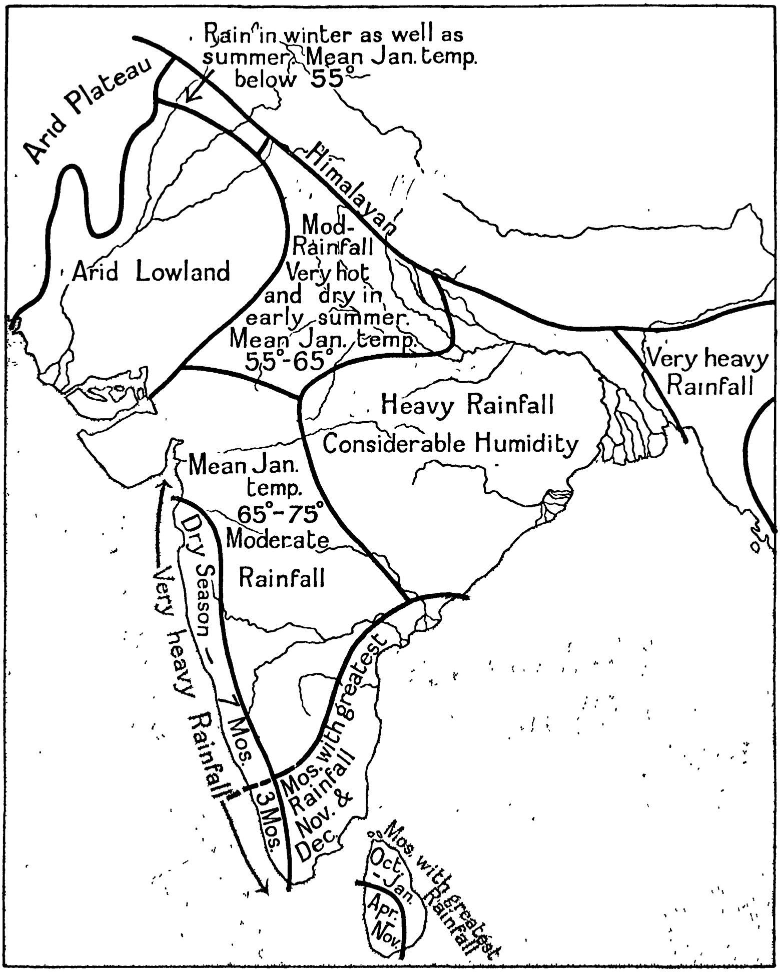


FIG. 68. Major climatic regions.

region; the north has very different conditions from the south, the coasts from the interior, the west coasts from the east coasts. Altitude introduces other and even larger variations, ranging from the Plains through the hill stations to the everlasting snows of the Himalayas. Fig. 68 shows the major climatic regions; their characteristics have been already indicated and need not be repeated. We shall describe as samples only the Carnatic as representing the south-east of the Peninsula

and east Ceylon; Bengal, a moist coastal region; the Punjab, part of the semi-arid Plains; Simla, a hill station; the Vale of Kashmir, an intermont basin near the front of the Himalayas; and Leh, in the upper Indus valley in the far interior of the mountains.

The Carnatic. The climate is distinguished by high temperatures and moist air throughout the year, and by the fact that most of the rain falls in October and November, during the retreat of the monsoon rather than during the monsoon proper. The term 'cold season' is a misnomer here for the early months of the year, since the mean temperature of the coolest month, January, at Madras is 77°; June is the warmest month with a mean of 90°, and May is almost as warm; the annual range is about 13°. The daily range also is small; in January the thermometer rises in the day to about 85° and does not fall much below 70° at night, so that the nights are much more oppressive than in the north-west. In May the mean daily maximum is about 100° and the mean minimum about 80°. The lowest record is 57°, the highest 113°. The uniform high temperatures are the less bearable because of the high humidity, which ranges from 65 to 80 per cent. April is particularly enervating with hot moist winds from the south.

In April and May occasional thunderstorms give 'mango-showers'. The arrival of the monsoon does not cause any pronounced increase in the rainfall, since the air has lost most of its moisture on the west side of the Peninsula; but the rainfall increases slowly till September, which has 5 inches, and then more rapidly, just at the time when over most of the Indian region the rains are ending and the fine weather of late summer is setting in, for north-easterlies are undercutting the retreating monsoon on the Bay, with very heavy rain in October (12 inches) and November (14 inches); December has only 6 inches, and by the end of the year the SW. monsoon has entirely withdrawn, leaving Madras under the influence of the dry NE. monsoon. The rain of October, November, and December is collected in large 'tanks' on which the irrigation of the region depends. In the east of Ceylon the rainy season is October to January, most rain falling in November and December.

Bengal. Here is the transition between the constantly high temperature and humidity of the south of the Peninsula and the dry bracing air and large range of temperature which characterize the north-west of the Plains. The land is low-lying, and has much inland water, rivers and creeks, irrigation canals and ditches, and swamps. Sea-breezes begin in February, and S. winds continue till October, making the air damp and relaxing. Moreover, Bengal as a whole is one of the rainiest regions.

The customary division of the year into three seasons, the cool season, the hot season, and the rains, holds good in Bengal as in the more westerly provinces, but the first is shorter and less bracing, and the heat of the second, if less intense owing to the greater dampness of the air, is on this account, perhaps, more trying to the European constitution. The rains are also longer and more copious (BLANFORD).

In March and April nor'-westers, with dust-storms and thunderstorms, give heavy rain. During the hot season Calcutta enjoys an advantage in the fresh sea-breeze of the late afternoon and evening.

At length in the early part of June, the clouds gather more thickly, while the barometer falls to a lower point than it has reached since the beginning of the year; and in the first or second week heavy and continuous rain ushers in the monsoon. This first burst usually accompanies a cyclonic storm, formed either at the head of the Bay or over the delta itself. . . . Its immediate effect is a great fall of the day temperature; and the comparative coolness, supervening on many weeks of close oppressive weather, brings a sense of relief. . . . When, however, in September the rainless intervals become longer, and the day temperature begins to rise, while the air, still highly charged with moisture, is almost motionless, the relaxed energy of the human system fairly rebels against this further trial of its endurance, and all who are not compelled by their vocations to remain at their posts hasten to escape to the temporary refuge of a hill station. September and October are thus the most trying and unhealthy season of the year (BLANFORD).

Punjab. A description is given by J. M. Merk, a resident in the province in 1880:

Like the rest of India, the Punjab has really but three seasons: the summer or hot season, the rains, and the winter, which we

speak of simply as the cold season. The hot season begins in April, but in March it is already so warm that barley and wheat ripen and are harvested. From April to June, as a rule, there is no rain. The west wind holds sway, and blowing from the sandy wastes of the Indus region, is a veritable hot wind. A denizen of the temperate zone can hardly realize the desiccating, truly scorching heat of the wind; it is like facing an open furnace. The thermometer rises in the shade to over 120°. In order to enjoy fresh air at this season one must take exercise in the early dawn, between 4 and 5 in the morning; for no sooner has the sun risen than the heat sets in again. After 7 a.m., save of necessity, no European leaves his house, and should business oblige him to do so, he must protect himself from the sun with a sunshade and a thick head-covering. . . . At sunrise, or soon after 5 a.m., houses must be closed, only a small door being left open for communication with the outside world. Thus the house of a European is more like a gloomy prison than an ordinary dwelling-house. So long as the hot winds blow strongly and steadily, rooms may still be kept in some measure cool by means of 'tatties' or grass screens set up in front of the doorway, and continually sprinkled with water, or by the fan vanes, which a servant keeps revolving and sprinkles with water; and at night the punkah is worked. Man and beast languish and gasp for air, while even in the house the thermometer stands day and night between 95° and 115°. Little by little the European loses appetite and sleep; all power and energy forsake him. Vegetation suffers equally; almost all green things wither; the grass seems burnt up to the roots; bushes and trees seem moribund; the earth is as hard as a paved highway; the ground is seamed with cracks; and the whole landscape wears an aspect of barrenness and sadness. At length, in June, the hot winds cease to blow, and are followed by a calm; and now indeed the heat is truly fearful; all things pine for the rains; but no rain, not even a shower, can one hope for, till the south and east winds shall have set in. And even then, the rains do not extend to the whole of the Punjab; Lahore has but little rain, Mooltan scarcely any; and the peasant of the Western Punjab is dependent entirely on artificial irrigation for the watering of his crops.

The southerly and easterly winds bring first clouds and violent storms with heavy rain showers, which are repeated daily, or, at all events, every 2 or 3 days, and, finally, the rains, which, in the Himalayas, set in at the beginning of July and cease at the end of August or in the middle of September. In July the trees begin a second time to burst into leaf; grass springs up once more, and soon a vegetation is developed that, fostered by warmth and mois-

ture, is scarce to be kept within bounds. The peasant now works hard at ploughing, sowing and weeding his fields. Rice is sown in June, during the great heat; in September it is reaped, and within two months maize is sown and harvested. . . .

After from 4 to 6 weeks of heavy rain, often falling uninterruptedly for 2 or 3 days in succession, it clears up, and sometimes some weeks pass without further rain; after which a week or two more of rainy weather brings the season to a close. Grateful as is the coolness brought by these showers, the more oppressively hot and sultry it is when the rain ceases and holds off, if only for half a day. The atmosphere weighs on one like a heavy coverlet; and then comes the daily and nightly plague of mosquitoes.

We can hardly picture in our European climate how serious and disagreeable are the effects of excessive moisture, as experienced towards the end of the rains. Woodwork swells, and doors and windows can be fastened only with much difficulty. Shoes and all articles of leather become thickly coated with fungus, books become mouldy and worm-eaten, paper perishes, linen becomes damp in the presses, and despite the oppressive heat one must often light a fire on the hearth, only to neutralize in some degree the influence of the damp.

The period which immediately follows the rains up to October is the most unhealthy season in the year. Decaying vegetation under an ardent sun generates miasma, the consequences being fever, dysentery, and not infrequently cholera. Towards the end of the rains, we rejoice indeed to see the heavy dark clouds disappear, but the heat soon becomes once more so great that we long for the cold season, and more than ever turn an anxious eye to the wind vane, watching for some sign of the cool westerly and northerly winds. With the beginning of October these winds set in steadily, clearing the skies, and now the blue firmament appears in all its splendour, so glorious in the torrid zone. . . . From October to Christmas, as a rule, the weather is clear and fine, the air is pure and most delicious, and a more charming climate can hardly be imagined; but it must never be forgotten that an Indian sun shines overhead, and that even in the cold season the unprotected head must never be exposed to its rays. For 5 or 6 weeks white men can work vigorously and with pleasure.

In December and January the fire burns all day long on the hearth, and in the morning and evening is especially grateful. The nights are positively cold; even on the plains ice and hoar frost form, and near the ground the thermometer sometimes falls to 23°. During the second half of the cold season we have in the Punjab a good deal of rain, without which indeed the barley and

wheat harvest is poor; the pulses also require the winter rains. In February we have a short spring; many trees unfold their leaves, and every bush furnishes its quota of flowery adornment. But this spring is of short duration, and in March it is already warm on the plains and the hot summer is at hand; an occasional dust-storm, however, for a while keeps off the summer heat. A dust-storm is indeed in itself unpleasant, the air being so charged with dust as to bring an Egyptian darkness, no matter what may be the hour of the day.

Simla on a ridge in the front ranges of the Himalayas has the same seasonal changes as the Punjab which it overlooks, but the altitude being about 7,000 feet the temperature is much lower; even the hot season is pleasant for Europeans, who find a haven of comfort after the furnace-heat of the Plains. The hottest month is June, when the mean temperature is 67°, about the same as in central Europe in that month; the mean daily maximum is 74°, the mean daily minimum 61°. January is the coldest month, with a mean of 39°, the same as in England. Frost is frequent in winter nights, the lowest temperature on record being 19°. Heavy falls of snow occur, and occasionally the snow-covering is several feet deep after a bad storm. The air is bracing and, except during the SW. monsoon, dry.

In January, February, and March the winter depressions cause heavy falls of rain and snow, the total precipitation amounting to nearly 3 inches in each month, twice as much as in the Punjab. April, May, and the first half of June have many thunderstorms with heavy showers, the representatives of the dust-storms of the Plains, and indeed clouds of dust sometimes extend into the hills; they nearly always occur in the afternoon. The air is remarkably dry in April and May, the mean relative humidity being only 45 per cent. The end of June brings a sudden and complete change of weather. The rain pours down during July and August, and the crisp dry air of April and May is replaced by air always damp and often saturated. The clouds hang low on the front ranges of the Himalayas, much lower in summer than in winter; Simla is often enveloped for days, even weeks, at a time, and the hill stations farther east are still worse off in this respect. In the middle of September the rains cease, and the weather is

beautifully clear, mild, and settled, and the sky cloudless till the end of the year. This is the most delightful season of the year, and all Europeans who can make for Simla or some other hill station. It is a favourite resort in the hot season also, but during the rains the ubiquitous damp and heavy rain make it undesirable. In the cold season it has some visitors, but many Europeans find it too cold.

Vale of Kashmir. The Vale is a flat-bottomed depression, about 100 miles long and 50 wide, through which the River Jhelum flows. It is behind the front ranges of the Himalayas, and in climate differs materially from the Plains; indeed it is comparable rather to Central Europe. At Srinagar in the middle of the Vale, 5,200 feet above the sea, the mean January temperature is 31°, about the same as at Berlin, and considerably lower than in England and at the most frequented hill stations in the Himalayas, which are some thousands of feet higher. The warmest month is July, not June as in most of the north, with the high mean temperature 73°. Thus the range of temperature is very large, a common feature in such enclosed basins. The air is always damp, the mean monthly relative humidity ranging from 71 to 82 per cent.; it is highest in the cold months. But the annual precipitation is low, only 26 inches. The driest months are October, November, and December, each with less than 2 inches; most of the others have 2 to 3 inches each. The heaviest precipitation is in the early months of the year, and is derived from the winter depressions. The 4 months January to April have 13 inches, the 4 months of the summer monsoon only 8 inches. The summer monsoon does not give much rainfall beyond the outer ranges. Most of the winter precipitation in the Vale of Kashmir is in the form of snow.

We are apt to think of Kashmir as part of the Indian region, and therefore as necessarily warm. As a matter of fact it lies 34 degrees north of the equator, in the same latitude as the northern part of South Carolina. In altitude it stands over 5,000 feet above the sea. Consequently the climate is comparatively cool. From November to March it is so cold as to be not only bracing but even rigorous. The spring and fall are mild and delightful, and the summer is warm. The great amount of water spread over the plain for irrigation, and the summer storms on the mountains

make that season damp though but little rain falls on the plain. . . . The temperate climate of the region, combined with the beautiful scenery, makes Kashmir a most attractive summer resort for the people of the Indian region, especially the English (ELLSWORTH HUNTINGTON).

The Vale seems to be suitable as not merely a summer resort but a permanent home for Europeans.

At *Leh* in Ladakh conditions are much less hospitable. We are here 11,500 feet above the sea in the upper Indus valley, which is settled by a scanty population between the altitudes of 9,000 and 12,000 feet; below 9,000 feet are impassable gorges, above 15,000 feet the climate precludes agriculture. The mean atmospheric pressure at Leh is about 680 mb. (20 inches). The mean temperature for the year is 41°, for January 17°; the 4 winter months have means below 32°. The lowest record is −19°, and the mean daily minimum in January is 9°. Temperature rises rapidly as summer comes on; in July the mean is 63° and the mean daily maximum 78°; the range both annual and diurnal is excessive. Water has been boiled (boiling-point 191°) by exposing it to the sun in a bottle blackened on the outside, and shielded from the air by a vessel of transparent glass. The rays of the unclouded summer sun are powerful but the shade temperature at the same time may be low. The precipitation is remarkably scanty, the total for the year being only 3 inches, and no month having over half an inch; most falls in the summer, July and August having half an inch, with a secondary maximum in winter. The mountains round about must have much more, and snow sometimes lies deep even in the valley in winter. Agriculture depends entirely on irrigation. The mean relative humidity is low, about 40 per cent. from May to November, 70 per cent. in the winter months; the air is often extremely dry, and always bracing.

CHAPTER XX

CHINA

Surface Features

China is a region of great size and variety of relief. It can conveniently be divided into north (north of the Yangtze basin) with which may be included for general description Manchuria and Korea, central (the Yangtze basin), and south (south of the Yangtze basin), a large area of broken hill country, most of it below 5,000 feet but rising to over 6,000 feet in the plateau of Yunnan. In north China the land rises abruptly from the extensive flat plains, on the west to the plateau of the interior of Asia which includes most of Jehol, Shansi, and Shensi, and on the east to the mountains of east Manchuria and Korea, which exceed 7,000 feet, and the highland and ranges of Shantung. In central China useful divisions are the Red basin of Szechwan, a well-watered upland plain about 2,000 feet above sea-level, and the damp lake region of the middle basin; on the north the region enjoys some shelter from the lofty ranges of the Tsingling Shan, the Tapa-shan, and other mountains against polar winds, but the ranges south of the Yangtze are less appreciated since they tend to cut off warm winds in winter, and to increase the sultry heat of summer by checking air-movement.

The climate of all the Far East is dominated by the great monsoonal wind-systems, and description must be based on them.

Pressure and Winds; Weather

In winter atmospheric pressure (reduced to sea-level) is very high in the interior of Asia 3,000 or 4,000 feet above the sea, and the gradient steep for northerly winds over China. Polar air of strongly continental type pours out from its source in Mongolia and north-east Siberia and descends in a wide cascade to the lowlands (Fig. 69). The prevailing and nearly constant winds are NW. and N. in north China, N. to NE. in central China, and NE. and ENE. in south China; the air is very dry as well as cold by its origin, but is soon warmed and moistened when it passes over the sea so that the windward

slopes of Korea and Shantung get considerable snow, and the damp NE. winds give south China a very different climate from that of the north. The winter monsoon is shallow, and is overlaid at about 6,000 feet by westerlies, dry and probably fairly constant winds of great velocity. The surface monsoon is of only moderate mean strength, but at intervals surges of stronger wind sweep down, led in by a cold front aligned from

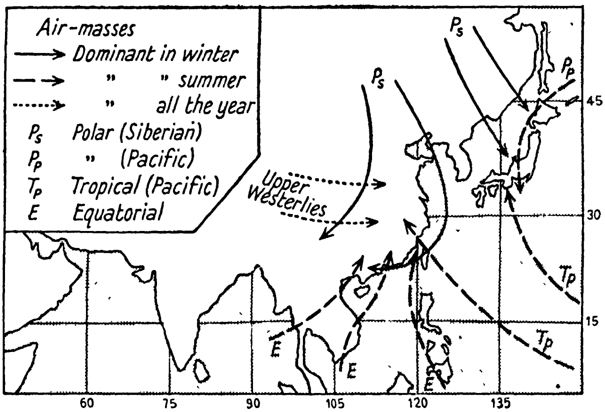


FIG. 69. Dominant air-masses in east Asia.

west to east and advancing south. In and for a long way behind the front the wind is often strong, and in a frontal belt the sky is cloudy or even overcast, with light rain or snow in north China and heavier precipitation in the south. In addition to these fronts other disturbances are frequent (Fig. 70); from the high pressures in the interior of the continent small detached anticyclones move off towards the east or south-east with southerly winds in their rear, and sometimes a definite though shallow trough develops between a pair of them, with much cloud and some precipitation, rain or snow, most in the Yangtze basin; the very cold polar blasts behind the troughs are much more prominent than the S. winds or any great warmth in front. Another class of disturbances includes the shallow cyclonic depressions, most of which appear in the west of the Yangtze valley and move slowly east giving much cloud and rain or snow on their passage; they form a prominent element in the climate of central and sometimes south

China, and are a feature of much meteorological interest. Some of them develop on the cold fronts of the monsoon described above; others have been shown to be associated with disturbances in the upper westerlies, and traced with some confidence across the continent in that current from the

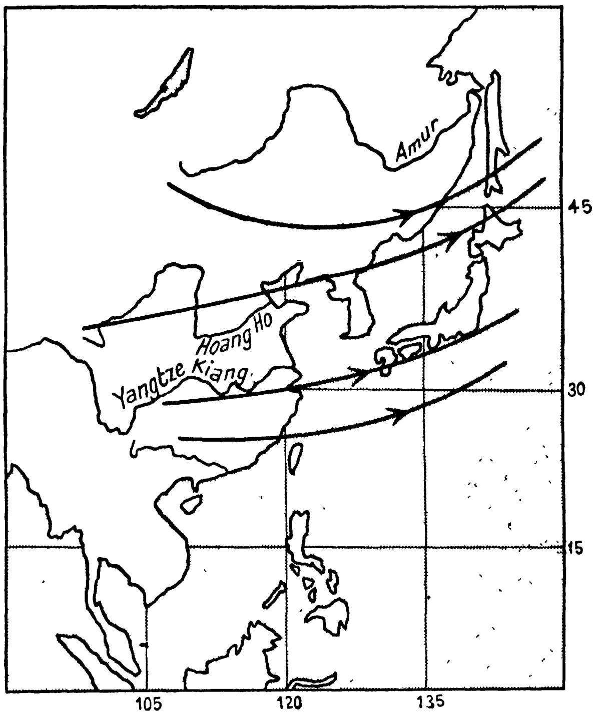


FIG. 70. Generalized tracks of continental depressions.

south-east of Europe. Others may originate as lee depressions in the winter monsoon under the ranges on the north of the Yangtze valley. Fig. 70 shows generalized tracks of the continental depressions; many are shallow and feeble, even difficult to identify, but they become more definite towards the sea. Shio Wang Sung gives averages of the number in the period 1921–30:

Jan. .	. 7	Apr..	. 11	July .	. 5	Oct. .	. 6
Feb. .	. 8	May.	. 10	Aug. .	. 3	Nov. .	. 7
Mar. .	. 9	June	. 8	Sept. .	. 3	Dec. .	. 7

Year . . 84

The south of China, with its tangle of hills facing the damp unstable air of the NE. monsoon, gets much low cloud and frequent rather than heavy rain or drizzle ('crachin') from the fronts and depressions approaching from the north. The plains of north China, on the other hand, get dry air and little precipitation, but suffer severely from dust and sand-storms; the strong winds associated with fronts raise clouds of fine dust as they sweep in turbulent gusts over the great expanses of loess, and carry them across the land to the coast and over the sea. Not only does the yellow dust in bad cases reduce visibility so as to be a serious obstacle to transport by land, sea, and air, it is always a scourge in ordinary life, especially in the worst areas where few days are free from it. The driest months, February, March, and April, are naturally the most dusty.

In the end of March the high pressures in the interior are weakening and the winter monsoon begins to break down; the prevailing winds are still northerly, but fronts with strong cold winds are fewer, and temperature is rising rapidly. In north China spring is a very dry season, not less dry than winter, and evaporation is more vigorous. In south China conditions in the transition period between the winter and summer monsoons are more complex. The northerlies are gradually replaced in April and early May mainly by tropical Pacific air from south-east, a warm and moist air-mass but not deep enough for very copious precipitation, though it gives more than the winter monsoon. The shallow Yangtze depressions continue to appear, and fronts still advance into south China from the north. In them the tropical Pacific air meets polar Siberian, and heavy widespread precipitation results. During May the anticyclone in the interior disappears, and a flat field of fairly low pressure, an extension from the very low pressures of south Asia, takes its place; at the same time south China begins to be invaded by deep masses of equatorial air, hotter and carrying more vapour than the tropical air, when the changing barometric gradient favours their advance from the Indian Ocean and the warm seas round Indonesia. They give very heavy rain in the sluggish northern fronts which still travel south, so that in the interior of south-east China and the middle of the Yangtze valley May and June

are the rainiest months of the year; on the south-east coast this early summer maximum is masked by the large rainfall contributed by typhoons in the late summer. Usually in early June the main equatorial air-mass arrives, a continuation of the SW. monsoon of the Indian Ocean, the 'burst' of which marks the beginning of the rains in the Indian region, and it sweeps over all south China, the heaviest rains marking the advance of its front. It soon reaches the Yangtze valley and is there responsible for the very rainy spell in the first half of June, the Mai-u or Plum rains, said to be so named because they come at the ripening of the plums, a time of very hot damp air, massive low cloud, and depressing weather. In July the equatorial air reaches north China, which has its heaviest rains in July and August, but the amount is much less than in the south except on the windward slopes of the Shantung Peninsula and the east of Korea.

Most of the rain of the summer monsoon is at the front of this advancing equatorial air, but other sources are thunderstorms in shallow thermal depressions, lee depressions, typhoons, and very heavy orographic rain. The weather within the equatorial air-mass itself is much less cloudy and rainy than near its front, and spells of fine weather are frequent; but the air is hot and damp, and the nights are specially oppressive for Europeans. The wind is too light to afford much relief from the sultry heat except where mountain- and valley-winds blow and, more generally, on the coasts where land- and sea-breezes are strong and regular. The Yangtze valley has a bad reputation for discomfort owing to its very light winds, much too light to temper the heat. In north China and Manchuria temperatures are almost as high as in the south, but the air is drier and the precipitation small, most of it falling in short thunderstorms, but occasional days have more than an inch, and the amounts are much larger in the mountains. Dust-storms are still a scourge in the rainy season as in the dry, occurring during spells of fine weather which leave the surface of the ground a prey to any wind.

September sees the end of the full summer monsoon; the equatorial air gradually retreats as pressure rises in the north, and bursts of cool polar air spread south with belts of rain along their fronts; typhoons continue to give heavy rain on

the coasts. But the general weather is fine, and pleasantly dry and warm in the south in the Pacific tropical air after the sultry heat of summer. The polar outbursts increase in number and intensity as the weeks pass, and become dominant in early November when the winter high pressures are re-established in Mongolia and Siberia, and a steep barometric gradient covers all the east of Asia.

The change of weather with the change of monsoon is the greater since the air-masses of the seasons are of strongly contrasted type. The constancy of the wind-directions, and the seasonal reversal, are striking:

MEAN PERCENTAGE FREQUENCIES OF WIND DIRECTIONS

	N.	*NE.*	*E.*	*SE.*	*S.*	*SW.*	*W.*	*NW.*	*Calm*
			North China (Gulf of Chihli)						
Jan.	25	6	5	*4*	8	13	11	23	5
July	6	7	11	19	26	12	*4*	7	7
			South-east China						
Jan.	18	49	21	2	1	*1*	1	2	4
July	6	5	13	10	25	21	7	*4*	9

TEMPERATURE (Fig. 71)

China has an 'east-coast' climate of a pronounced type, with remarkable extremes, and striking contrasts between north and south.

Winter is cold, extremely cold, dry, and dusty in the north, and not warm for the latitude in the south. The isotherms for January (Fig. 40) trend gradually south in their course over Eurasia to attain their most southerly position on the China coast, the 32° line in lat. 35° N.; the same line runs farthest poleward on the west of Eurasia. The cold is intensified by the absence of an efficient mountain-barrier against the polar air-masses; China may well envy India sheltered under the Himalayas. But parts of the region have valuable wind-breaks in the high west–east ranges of the Tsingling, the Tapa Shan, and other ranges, the Red basin of Szechwan being specially favoured. South China is much warmer than the north thanks to its lower latitude, but another factor is that its monsoonal winds are warmed by a long passage over the China Sea. Frost and snow occur throughout China, even at Hong Kong and Canton, where, however, they are very rare.

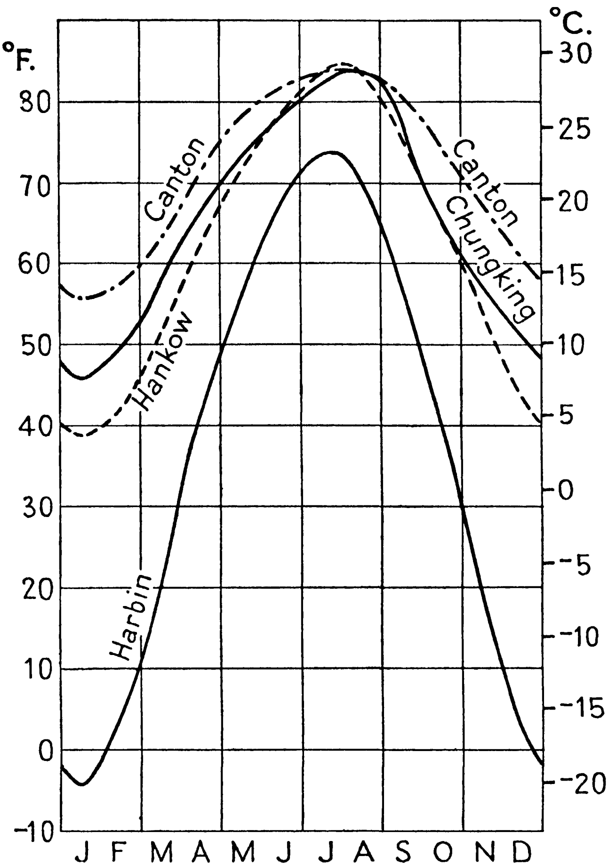


FIG. 71. Mean temperatures.

All the rivers of the north are frozen for some months:

	Mean Dates	
	Freezing	*Thawing*
R. Amur, at and above Blagoveshchensk .	mid-Nov.	mid-May
R. Sungari	,,	,,
R. Yalu	end of Dec.	end of Mar.
R. Liao	,,	,,
Hoang Ho (lat. 40° N.)	mid-Nov.	mid-Mar.
Rivers of the Great Plain of north China .	,,	,,

The Gulf of Chihli freezes near the shores and even to 50 miles out in very severe winters; navigation is occasionally stopped on the west of Korea north of lat. 38° N.

Summer presents a great contrast; the cold of winter is changed to heat abnormal for the latitude, and the large range of temperature from north to south to a similarity remarkable for such a vast area. Illustrative data are:

MEAN TEMPERATURE

	Jan.	*July*	*Annual range*	*Abs. extremes*
Harbin	−1	73	74	−36, 98
Hankow . . .	40	86	46	13, 106
Hong Kong . . .	60	82	22	32, 97
Difference, Hong Kong–Harbin . . .	61	9	−52	68, −1

For more details see descriptions of the major climatic regions.

PRECIPITATION

Almost the whole is in the summer half-year; the air-masses which bring the vapour and the meteorological conditions of its precipitation have been described in the section on pressure and winds. The amount is largest in the south and east, where the hills between Hangchow Bay and the Gulf of Tonkin have annual means of about 60 inches. The 40-inch isohyet follows the middle and lower Yangtze; north China has 20 to 25 inches, Manchuria only 15 to 25. Most of the rain falls within 4 months so that those months' totals are large, and even in normal seasons the rivers rise to high floods, the Yangtze on the average 70 feet above winter level at Chungking and about 40 feet at Hankow. Very heavy downpours are not uncommon, over 3 inches in 24 hours in north China, and over 7 inches in central and south; Hong Kong has had 21 inches. Such torrential rains denude the treeless hills, flood the plains, and destroy and bury the fertile cultivated lands; the loss of life and damage to property are almost as serious as those due to droughts.

Precipitation is very variable. North of the Yangtze valley even the mean is none too much for a land with a short agricultural season and a large population always near the limit of subsistence, and the frequent droughts and deficient rains entail famine. The south is in better case, for the rainfall is larger and less variable, and agriculture continues all the year. On the other hand, throughout China abnormally heavy rain may persist and cause most disastrous floods.

Most of the rain is associated with the summer monsoon, but north, central, and south China have their own régimes (Fig. 72). The north has the simplest; Tientsin gets 89 per cent. of its annual total, 21 inches, in the months May to September, the other months have less than 1 inch each; the amount increases till July and August and then decreases as the mon-

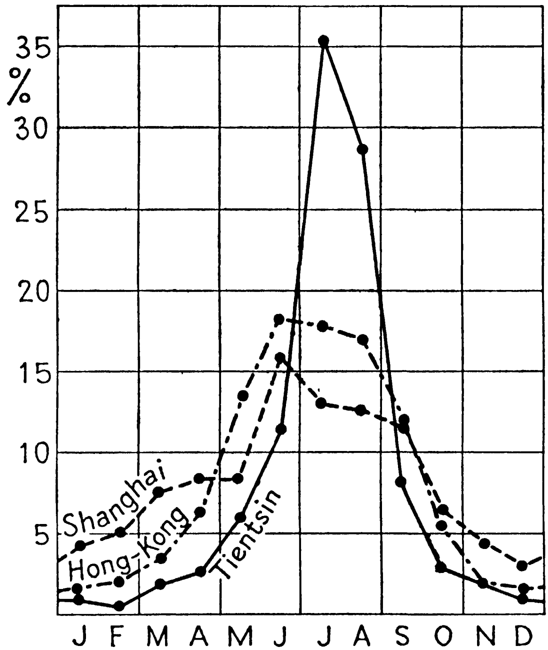


FIG. 72. Mean monthly precipitation, percentage of yearly total.

soon weakens. South China has a similar régime but larger totals, Hong Kong 85 inches a year and no month less than 1 inch. The rain begins to be heavy in March and increases to a maximum in June; each of the 5 months May to September has 10 inches or more. Thus the main features are the heavy summer rain, the early maximum, and the scanty but appreciable rain in winter. The régime in the other region, central China, shows that while most of the precipitation falls in the summer monsoon the periodicity is not so strong as in the north and south; Shanghai has only 61 per cent. of the annual total in the 5 months May to September and no month except December has less than about 2 inches; June and July have

most, but winter gets a considerable share. Hankow in the interior gets 60 per cent. in the same 5 months. Data illustrating the three régimes are:

MONTHLY MEANS

	Tientsin		*Shanghai*		*Hong Kong*	
	Amount	*Rain-days*[1]	*Amount*	*Rain-days*[1]	*Amount*	*Rain-days*[1]
Jan. . .	0·2	1	1·9	6	1·3	4
Feb. . .	0·1	<1	2·3	9	1·7	5
Mar. . .	0·4	2	3·3	9	2·9	8
Apr. . .	0·5	2	3·7	9	5·4	7
May . .	1·1	4	3·7	9	11·5	11
June . .	2·4	6	7·1	11	15·5	18
July . .	7·4	10	5·8	9	15·0	18
Aug. . .	6·0	9	5·6	9	14·2	14
Sept. . .	1·7	4	5·1	11	10·1	13
Oct. . .	0·6	1	2·8	4	4·5	6
Nov. . .	0·4	2	2·0	6	1·7	2
Dec. . .	0·2	1	1·4	6	1·1	3
Year . .	21·0	43	44·7	98	84·9	109

[1] With 0·04 inch or more precipitation.

THE MAJOR CLIMATIC REGIONS (Fig. 73)

The divisions are based on the broader features; many subdivisions might be made, but only the larger features can be considered here. The descriptions aim at stressing the outstanding peculiarities rather than giving complete accounts.

1. Mongolia (representative station, Ulan Bator (Urga)). A vast desert plateau with a border of poor steppe on the south-east. Mean annual precipitation less than 10 inches, nearly all in summer, but very variable. Winters extremely dry and cold (January mean temperature below 0° F.); summers hot (July mean about 65°) with blazing sun, strong winds carrying clouds of dust by day, followed by calm clear nights.

2. Tibet. See Chapter XXIV.

3. Manchuria (Harbin, Dairen). The most prominent feature is the long and bitterly cold winter. In the interior 5 months, November to March, have mean temperatures below 32°, January below 0°; the daily minima in January are often below −30°, and Harbin has recorded −36°. The cold is less severe in the south near the sea, where Newchwang has only 3 months below 32° and an absolute minimum of −24°, but bitterly cold strong winds sweep down through

the openings where the Yalu and Liao rivers reach the sea. All rivers are frozen, for about 6 months in the north, 3 to 4 months in the south, and the harbours are ice-bound. Agriculture and other outdoor work is suspended; thick wadded

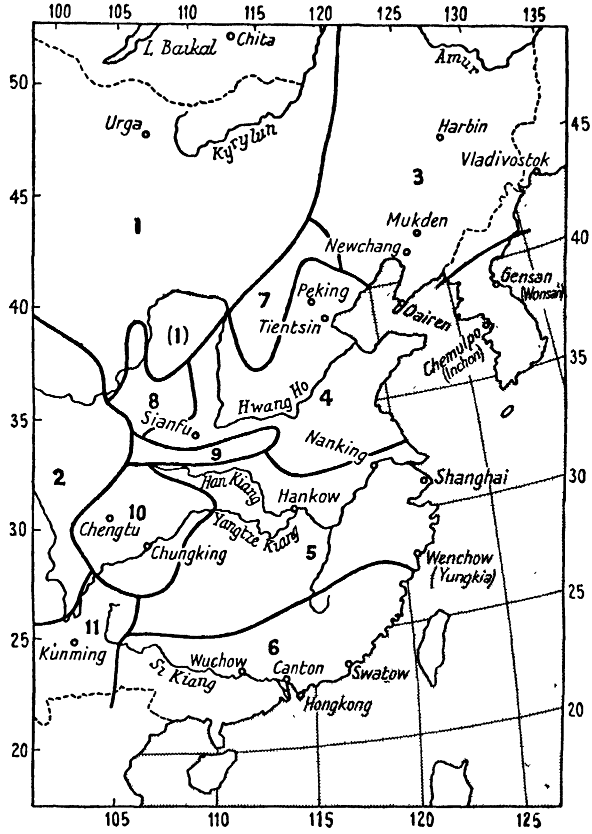


FIG. 73. Major climatic regions of China.

garments are the universal wear. After a few weeks of transition May brings the heat of summer with mean temperature about 60°, and agriculture is at once in full swing; the heat increases rapidly till July when the monthly mean rises to over 70° in the north, and about 78° in the south, with daily maxima usually well over 80° and extreme records up to about 100°. In October temperatures are falling fast and November grips the whole country in the intense cold of

winter. The magnitude, and consequently the rapidity, of the change from summer are outstanding among the climatic extremes on the globe.

Nearly all the precipitation is in the 6 summer months, most of it in June, July, and August, so that it is abundant in those months though the annual mean is only about 25 inches in the most favoured region, and suffices for good crops of wheat, millet, and other products. But much of the west gets less and is little better than poor steppe or semi-desert. As in all China, a great obstacle is the unreliability of the rain, the more serious in these areas on the margin of cultivation, and the vigorous evaporation under the powerful sun and strong drying winds of spring robs the land of much of its water. All the winter precipitation is snow, but it is scanty in the interior. The yellow dust in the air in the dry months is very unpleasant everywhere, and the dust-storms of late winter and spring in the south of Manchuria are a veritable scourge.

4. North China (Peking). Like the preceding regions a land of great extremes, cold dry winters with means below 32° in at least 1 month and 3 months in the north, and hot, humid, almost equatorial summers, with July means about 80° and absolute maxima up to about 110°. Thus both the winters, and in less degree the summers, are warmer than farther north. The rainy season is short, June to September, and the mean rainfall little more than 20 inches, not only scanty but very variable in amount and time. Disastrous droughts are frequent, and also devastating floods which inundate thousands of miles of the flat low country. The impalpable yellow dust in the air, and particularly the dust-storms associated with strong winds from the interior in the dry months of late winter and spring, which are very frequent and intense in much of China north of the Yangtze, are not only unpleasant and irritating physiologically but a danger for all forms of transport by reducing visibility both on land and far out to sea; the haze often rises to over 10,000 feet. Other forms of bad visibility are the occasional surface inversion-fogs in the interior on calm winter nights, and the frequent sea-fogs of spring and early summer, condensed in warm, damp, tropical air moving north over the inshore waters which are still cold; they sometimes cover great areas of the sea and are carried

well over the littoral, particularly round the Shantung and Liaotung peninsulas and on the east of Korea.

5. The middle and lower Yangtze basin (Hankow, Shanghai). We have left the intensely cold dry winters and the scanty rainfall of north China. The mean January temperature is well above 32° (rather lower near the coast than up-country) and severe frost is rare, though the night minima are usually about freezing-point (absolute minimum at Shanghai 10°). Summer is long and hot, the monthly means exceeding 80° in July and August; the daily maxima in the same months are usually about 90° (absolute maximum at Shanghai 104°) and the temperature does not fall much below 75° at night, very high figures, and the heat is the more trying owing to the high humidity. The mean precipitation is about 45 inches, and each of the months of the summer monsoon has more than 5 inches; early summer, June and July, has most rain. Precipitation is appreciable in winter, when part of it is snow. Double crops are raised in the lowlands, rice in summer, wheat and millet in winter.

6. South China (Wuchow, Hong Kong) is the most luxuriant region, with agriculture in full vigour all the year, yielding a succession of three crops. Winter is almost as warm as July in England (but slight frost may occur inland), and has enough rain to keep the land green; the sky is often cloudy but many days are bright and sunny, making a delightful season, especially in the hills, for Europeans; tropical clothing is worn most of the year. The long summer, on the other hand, is hot (4 months having means above 80°) and humid with heavy rain, at Hong Kong more than 10 inches a month in May to September, making 66·3 inches in that period. The coasts especially are enervating in summer, and the hills are little better, for though cooler they have more rain and moister air. Typhoons are an affliction in summer and autumn, doing much damage on the coast; most recurve towards the north-east before reaching the land, but some cross the coast which then suffers fearful havoc from their fury (p. 226). The number of these in the 31 years 1904–34 was:

Jan.	0	Apr.	0	July	44	Oct.	5
Feb.	0	May	0	Aug.	47	Nov.	1
Mar.	0	June	6	Sept.	35	Dec.	0

7 (Yangku, Taiyuan). This mountainous region has 15 to 20 inches of rain, more than the steppes of Mongolia but less than the Great Plain; it is scanty for mountains, and the rainy season is short, very little rain falling except in the months March to September. Winter is very cold, dry, and windy, with ubiquitous dust-haze. Summer is warm but not hot.

8 (Changan, Sianfu). A much dissected plateau of loess, altitude 4,000–5,000 feet. Precipitation is less than 20 inches, nearly all in summer but with occasional snow in winter. Winter is very cold and dust-storms are frequent, summer is pleasantly warm. The low rainfall, vigorous evaporation in the dry air under the strong sunshine of spring, the very dry desert winds, and the permeability of the loess prevent agriculture except where irrigation can be used in narrow valley strips.

9. The Tsingling Shan and adjacent mountains, the ranges exceeding 10,000 feet in the middle of the division and 5,000 feet in the east; in the west they join the lofty plateau of Tibet. The climate is of the mountain type, and the region is an important divide between the arid or semi-arid north-west and the warm, damp, and well-watered south.

10 (Chengtu, Chungking). The Red basin of Szechwan is characterized by its warm winters due to high ranges on the north and east warding off the winter monsoon, and to the many south-facing slopes which enjoy strong insolation. Chungking (altitude 755 feet) has a mean of 45° in January; frost is uncommon and never severe; summer is hot, as in most of China, the hotter here in the absence of much wind, the means of July and August exceeding 80°. Chengtu, at a greater altitude, 1,610 feet, in the west, is rather cooler but yet has means of 43° in January and 79° in July. The mean annual rainfall ranges from 30 inches in the north to over 40 inches in the south, most of it being in the months April to October, but useful rain falls in all months except January and February. The Yangtze valley is damp and cloudy, especially in winter when Chungking often has no sunshine for weeks together, but the rest of the Red basin enjoys clear skies and generally fine weather, but with high humidity and frequent fog over the irrigated land. Thanks to the warm

winters, good rains, and abundant water for irrigation agriculture is intensive, giving two crops a year and in the best areas three.

11. The plateau of Yunnan (Tengchung, Kunming), altitude 6,000 to 8,000 feet, differs in climate as well as in topography from the broken hill country of south-east China. Thanks to its height it has a good rainfall, 40 to 60 inches a year, most of it in the months May to October with maximum in July and August, but winter is not rainless. The climatic advantage is greatest in the cold season, when the plateau rises above the shallow winter monsoon and its disturbances into the dry air and almost cloudless skies of the upper westerlies, making winter a very pleasant season for Europeans, cool but not cold (January mean about 50°, frost infrequent and never severe, snow rare), dry and sunny; but on occasions the NE. monsoon is deep enough to surmount the plateau, bringing bad weather, windy, cold, rainy, or snowy. Summer has less pleasant weather than winter; the deep equatorial air of the SW. monsoon covers the plateau giving it a humid warmth, much heavy low cloud, and heavy rain (about 10 inches in July and in August). The deep valleys in the west are sultry and malarial.

CHAPTER XXI

JAPAN

(*For place-names see Fig. 76*)

Winds

The climate of Japan is controlled by the great monsoonal air-movements already described for China, but the winter monsoon is much modified by the mountains and by the insularity of Japan, which is 300 to 500 miles out from the mainland beyond the Sea of Japan. The very cold, dry, continental polar air from Siberia becomes warmer, damp, and unstable, indeed it is almost changed to maritime polar air, in its sea passage (Fig. 74), the effect being the greater since a warm stream of the Kuro siwo washes the west coast of Japan; the mean temperature in January is 6° at Vladivostok on the Siberian coast, 35° at Niigata on the Japanese coast opposite. The islands lie athwart the air-stream, and the contrast between their windward north-west and leeward south-

east sides is increased by the relief. The former is exposed to all the strength, and sometimes fury during the passage of fronts, of the cold monsoon with its overcast skies, rain- and more often snow-storms which are heavy even over the sea before the mountains add their influence; the latter gets shelter, more effective in the south, and has comparatively dry,

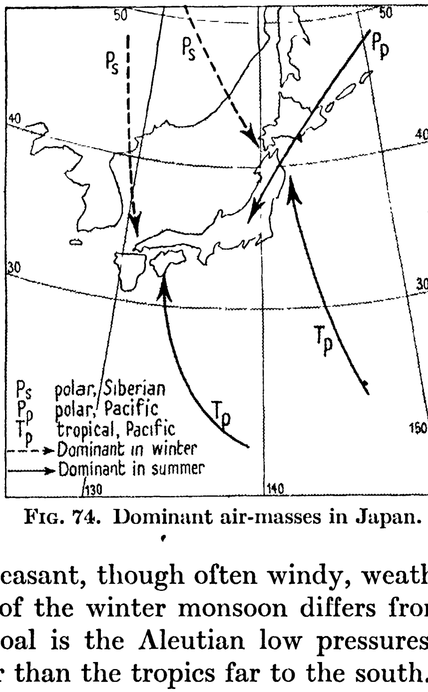


FIG. 74. Dominant air-masses in Japan.

sunny and pleasant, though often windy, weather. The Japanese branch of the winter monsoon differs from the Chinese in that its goal is the Aleutian low pressures of the north Pacific rather than the tropics far to the south.

The summer monsoon, very light winds from the south, blows along, not across, the islands, and local differences are not prominent except in respect of the amount of precipitation.

The mean percentage frequencies of the winds in winter and summer at representative stations are:

	N.	*NE.*	*E.*	*SE.*	*S.*	*SW.*	*W.*	*NW.*	*Calm*
Tokyo, Jan. . .	30	6	2	5	4	3	6	43	1
July . .	10	11	9	20	32	8	3	6	1
Miyako, Jan. . .	11	3	2	1	4	5	65	7	2
July . .	20	21	5	4	11	11	22	3	3
Niigata, Jan. . .	6	3	4	10	18	10	21	26	2
July . .	18	13	5	14	14	14	12	6	4
Nagasaki, Jan. . .	37	15	8	9	2	2	4	18	5
July . .	7	5	6	15	12	31	13	3	8

The winter monsoon, strong and often stormy, is dominant in the months October to April; the summer monsoon in May to September is much lighter and variable in direction and force. In some localities the general winds are deflected by the bold relief.

Thus Japan resembles China in summer, but it has warmer and damper winters, with more precipitation and less dust than north China and Manchuria in the same latitudes; the annual range of temperature is much smaller.

Precipitation

The main features of the advance of the summer monsoon and the heavy rains along its leading front are similar in Japan and China; in Japan tropical air from the North Pacific forms a larger part of the monsoon and equatorial air a smaller part than in China. The precipitation increases fast from winter (which has a considerable amount) to a maximum in the Bai-u, the 'plum rains', from mid-June to mid-July, a very cloudy, damp, and rainy period associated with shallow depressions, most of which advance slowly north-east to Japan from the frontal belt in central China (Fig. 70). Then, abruptly, the monsoon is fully established and gives fairly fine but very hot and sultry weather.

The heavy rain of late summer is in part frontal, at the meeting of the NW. monsoon, which is now spreading south, with the retreating tropical air-mass, in part associated with the typhoons and similar but less intense cyclones which are now most numerous. The majority form east of the Philippines, and move first north-west and then north-east, following the warm waters of the Kuro siwo (Fig. 79); indeed, the warm current is a favourite track for depressions all the year, a fact which helps to explain the absence of a dry season in Japan. Most typhoons are reduced in intensity before they reach Japan, but they give much rain, which tends to fall in heavy showers (in contrast to the bai-u), and some do much damage in the south and south-east.

In addition to the bai-u and the late summer rains, rain and thunder are often associated with shallow local thermal depressions throughout the summer as in China; orographic rain also is naturally very prominent in these mountainous islands.

The winter precipitation, most of it snow in the west and north, is much heavier than in China; but in all Japan, except the west of Honshu, summer is very definitely the rainy season (Fig. 75). The mean annual totals range from about 80 inches in the south to 40 inches in Hokkaido, with the usual orographic increase, to over 160 inches in places; on the other hand, the totals fall to less than 50 inches on the Inland Sea.

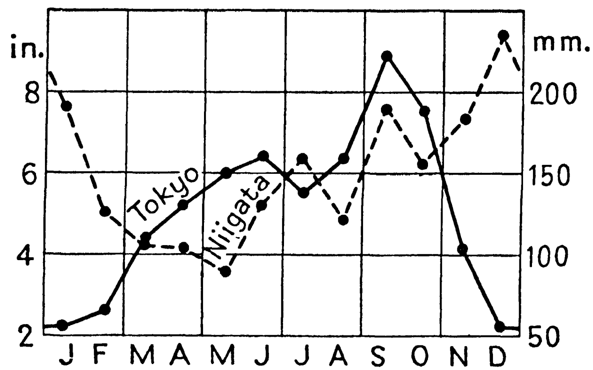


FIG. 75. Mean monthly precipitation.

THE MAJOR CLIMATIC REGIONS

A division of Japan into climatic regions is necessarily based on the winter, not the summer, conditions; the mean temperature of January in the south is about 27° higher than in the north, that of July only 14° higher.

January is the coldest month, August the warmest. Summer is hot and sultry except in the north, the nights being especially trying; tropical clothing is the usual wear. Winter is cold except in the south-east, less cold than in China, but colder than in west Europe in the same latitudes.

The main regions are shown in Fig. 76.

1. Hokkaido (representative stations Sapporo, Nemuro) owes its distinctive features to its northern position. The west coast is fully exposed to the NW. monsoon, which is coldest in these higher latitudes, and less warmed in its shorter sea passage; the Pacific coast also is often exposed to it in cyclonic weather. The many depressions from Manchuria become more intense over the sea, and give fierce gales with heavy snowstorms.

The winters are very cold for the latitude, 4 months having mean temperatures below 32°; the January mean falls from 25° in the south of the island to 18° in the north, and much lower on the mountains. The night minima in the months December to March are usually far below freezing-point (mean daily minimum in January being about 16°), and the maxima

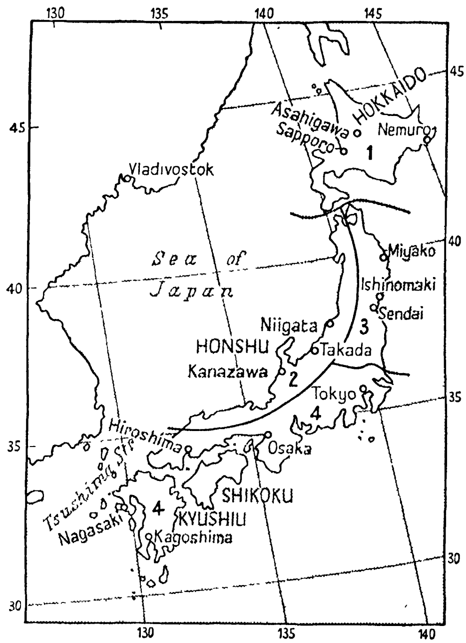


FIG. 76. Major climatic regions of Japan.

do not rise above freezing-point in the day. Asahigawa has recorded −42°. Spring is but a short transition period, and summer follows with heat in remarkable contrast to the cold of winter; the August mean on the littoral is about 70°, with mean diurnal extremes 75° and 65°.

The mean annual precipitation is about 40 inches, most of it in the summer monsoon, but snow accounts for 2 inches or more (of equivalent rain) in each of the winter months.

For 5 months, November to April, the whole island is under snow, very deep in the west and on the mountains. The west has cloudy gloomy weather, but the Pacific coasts are much

clearer. In summer the latter have the disadvantage of frequent dense sea-fogs, which chill the air already cool near the cold waters of the Oya siwo.

2 (Niigata). Winter is very severe on this littoral and the adjacent mountains, the NW. monsoon often rising to gale force so that shipping is held up; the air is damp, the sky nearly always overcast, and sunny days very exceptional; precipitation is frequent and heavy, nearly all in the form of snow in the north and on the mountains and much of it in the south, for about 5 months from mid-November in the north, 3 months from mid-December in the south. The snow sometimes falls with little intermission for days, and often lies to a depth of 6 to 10 feet and even more in the windward upper valleys, so that communications by road and rail are interrupted, outdoor work is suspended, and many of the people migrate to work for the season in more open localities.

At Takada the depth of snow was 12 feet on 9 February 1927; in it and other cities in the west of Honshu the houses have long eaves, and the ground under them is the only thoroughfare since the snow covers the streets so as to reach the level of the second storeys of the houses (OKADA).

After a few weeks of transition from winter to summer, for spring is a very short season everywhere on the lowlands of Japan, the summer monsoon brings heat, damp air, and heavy rain. Thus this region has heavy precipitation, both in winter when it is at a maximum, and in summer when it is much less but still very large (Fig. 75); the annual total is among the largest in Japan.

The large range of temperature between the cold winters and the summers with almost equatorial heat is characteristic of most of the Far East, but this region has the remarkable peculiarity of a very heavy snowfall in winter.

3 (Ishinomaki). The north-east of Honshu, though on the Pacific side, resembles region 2 in its cold snowy winters, the mountains not being an effective barrier against the storms of the NW. monsoon. Heavy snowfalls cover the ground, though less deeply than on the west, and communications are often interrupted in the north; the mean winter temperature is rather lower, but the skies are much less cloudy, and the

weather brighter and more exhilarating. In summer also this region is cooler than the west, owing mainly to the branch of the cold Oya siwo which washes the coast.

The mean annual precipitation is 40 to 60 inches, but rises to about 80 inches on the mountains. It is heaviest in summer, the winter snow giving a secondary maximum, but in districts most exposed to the winter monsoon the winter total is the larger.

4 (Tokyo, Kagoshima). This region has a great advantage in winter of southerly position and a much indented coastline with strong maritime influence, especially round the Inland Sea. The mean temperature in January exceeds 40° in the lowlands.

In the plain north of Tokyo the winter weather is usually fine, with clear skies and few storms of rain or snow, but cold dry NW. winds often sweep down, and the shelter of hills or even of screens of trees is welcome. Frost may occur as late as April. The winters are milder in the south of Honshu and in Shikoku and Kyushu, the more so in places like Osaka with hills to ward off the NW. winds and in the peninsulas which project into the Pacific; the Inland Sea has the benefit of shelter by hills and warmth from its water-surface. Kyushu is most favoured by position and indented coastline, except the north-west which has the disadvantages of the whole of the north-west side of the islands though in less degree, being exposed to the cold damp winter monsoon, with its cloudy skies and snow-storms; Nagasaki, despite a certain amount of shelter, has recorded a minimum 22°.

Summer presents the strong contrast usual in the Far East. The heat and high humidity are oppressive, with daily maxima about 87°, except on coasts which enjoy a sea-breeze. Even the night minima average 73° to 75°, and the sultry moist heat is the more trying in the calm air.

On the ocean side of southern Japan the palm tree, the orange, and the camphor flourish. Small islands near this coast may be found covered with flowers at the beginning of February, when the lake of Suwa in the interior of Honshu is frozen over so that fairs are held on it (OKADA).

Precipitation is abundant, 50 to 70 inches a year; much water is supplied also by melting snow on the mountains,

which are still fairly well wooded so that the run-off is regular. Summer is the rainy reason; June is the rainiest month with means up to about 14 inches in places, and a secondary maximum is usual in late summer. The driest months, December and January, have 2 inches or more; snow is not frequent, and does not lie long.

Representative data are:

MEAN TEMPERATURE

	January			*August*		
	Mean for month	*Mean daily max.*	*Mean daily min.*	*Mean for month*	*Mean daily max.*	*Mean daily min.*
Tokyo . .	39	47	29	79	86	73
Hiroshima . .	40	48	31	80	90	73
Kagoshima. .	45	53	37	80	87	74

CHAPTER XXII

INDONESIA. SOUTH-EAST ASIA

(*For place-names see Fig. 77a*)

THE Indonesian region is characterized by its low latitude within the inner tropics, its insularity, hot seas with mean annual surface temperatures about 84° (the highest on the globe), and position midway between the monsoon areas of south-east Asia and north Australia. South-east Asia extending to 20° N. is included for convenience, but it differs in many ways from Indonesia. All the islands are mountainous; New Guinea, Borneo, and Sumatra are so large that they lack many of the usual features of islands, and Malaya so narrow as to be insular in spite of its continental connexion.

AIR-MASSES AND WINDS

The great monsoonal air-masses which originate in far distant sources in north Asia and Australia and the adjacent oceans sweep over the region (Fig. 77), but their character is much modified by their long passage. Even the continental polar air of Asia becomes tropical, warm and humid, in the north of the region, and equatorial on and beyond the equator; the Australian air is much warmer at its source and

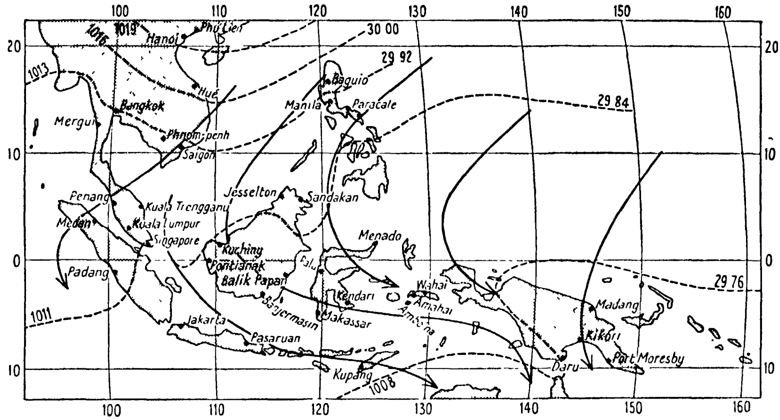


FIG. 77*a*. Mean isobars (broken lines) and streamlines, January.

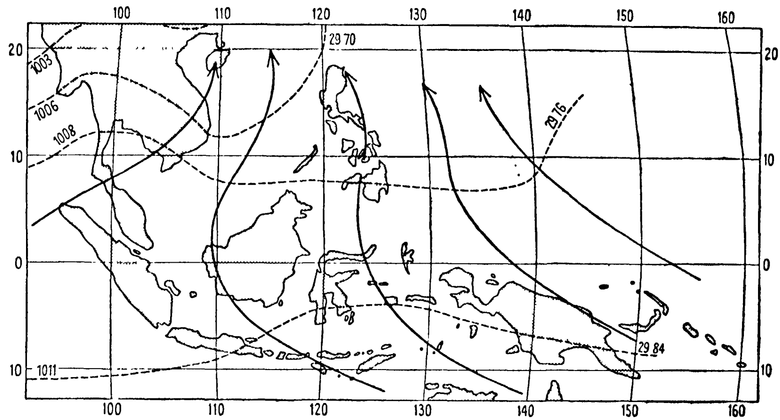


FIG. 77*b*. Mean isobars and streamlines, July.

WIND DIRECTIONS. MEAN PERCENTAGE FREQUENCIES

	N.	*NE.*	*E.*	*SE.*	*S.*	*SW.*	*W.*	*NW.*	*Calm*
Singapore, Jan., 0900 .	18	48	1	0	0	0	1	6	26
1500 .	10	48	3	4	1	4	2	6	22
July, 0900 .	1	2	5	29	16	15	4	2	26
1500 .	0	1	1	22	15	31	5	5	20
Amboina,[1] Jan. . .	13	16	7	3	3	7	13	19	19
July . .	0	16	39	26	3	0	3	3	10
Jakarta (Batavia),[2] Jan.	12	5	2	4	7	8	17	18	27
July	10	18	17	15	9	2	1	2	26

[1] Mean of 0600, 0900, 1500, 2000. [2] Mean of 24 hours.

is hot and moist when it reaches the equator, but is still dry between Australia and lat. 5° S.

The northerly monsoon is dominant in the months December to March (November to April in the north); it is known as the west monsoon in and south of the equatorial zone; the southerly monsoon, known as the east monsoon, blows from May or June to September (see table, p. 215).

The intertropical convergence swings north and south across the region, appearing over the extreme latitudes once, over the inner tropics twice, in the year.

In the transition months the winds are light and variable everywhere, and in the equatorial zone within about 5° of the equator they continue so all the year. In the south, between 5° S. and Australia, they are steadier and stronger, often exceeding force 4 at sea, during both monsoons; in the north, between south-east Asia and the Philippine Islands, they are still steadier and stronger and sometimes rise to gale force in winter, but the summer monsoon is sluggish, light, and variable. In Indo-China both the NE. and the SW. monsoons are deflected to follow the coasts, the former blowing from between N. and E., the latter between S. and W. In Indonesia the winds blow, in many places strongly, along rather than across the channels between the islands, and local peculiarities are prominent also on the coasts; the Barat, a strong and squally W. wind in the N. monsoon along the north coast of Celebes, is occasionally violent enough to do damage. Almost every one of the numerous channels has its squalls, clouds, and other features for which the navigator must allow. During the SW. monsoon the Malacca Straits are liable to Sumatras, strong squalls advancing across the Straits from the south-west with a NW.–SE. front, sometimes more than 100 miles long; they may last for some hours, blowing at force 7 or 8 (gusts up to 50 miles an hour), with violent thunder and lightning and heavy rain. They are essentially night visitations, and they seem to be strong surges in the monsoon, intensified by a katabatic effect in the mountain-ranges of Sumatra. They reach the Malay coast as well as the Straits, but do not extend far inland. The south coasts of New Guinea, especially near the mouth of large valleys in the high adjacent ranges, are subject to strong squalls ('Guba') usually with heavy rain and thunder, which

occur in the night, mostly during the NW. monsoon; they are similar to the sumatras of the Malacca Straits.

Land- and sea-breezes mask the general winds on most of the island coasts; the sea-breeze is the stronger and more important except on coasts under mountain-ranges where the land-breeze is much intensified; the strength of both depends on their direction reinforcing or counteracting the general winds of the district. Mountain- and valley-winds are prominent.

Temperature

In the central belt the temperatures are those usual in the inner tropics, high but not excessive all the year; the mean annual range is so small that temperature does not serve to distinguish the seasons. The annual mean near sea-level is about 79°, and the monthly means range from 78° to 81°. The daily range much exceeds the annual, but is by no means large, averaging 12°; the heat of the seas and the high humidity of the air preclude great extremes. The weather is sultry, hot and damp, and even more oppressive at night when the air is usually calm than in the day, making a monotonous, 'sticky', climate. The humid heat is expressed numerically in comparable series of dry- and wet-bulb temperatures:

Mean Temperature

	Jan.	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*
Singapore												
Dry-bulb	77·9	78·4	79·3	79·9	80·6	79·9	80·2	79·7	79·5	79·7	79·0	78·3
Wet-bulb	74·7	74·1	75·4	75·7	76·6	75·7	75·9	75·4	75·2	75·7	75·4	75·0
Jakarta												
Dry-bulb	77·7	77·7	78·4	79·2	79·5	78·8	78·4	78·6	79·2	79·3	78·8	78·3
Wet-bulb	75·0	75·2	75·6	76·1	75·9	75·2	74·3	73·9	74·3	74·8	75·2	75·0

The annual range increases rapidly with latitude, the summers getting appreciably hotter and the winters much cooler, particularly in the north. In Tonkin the January mean is only 62°, and sudden drops of as much as 30° are liable to occur, snow occasionally falling on the mountains above 5,000 feet; the mean temperature of the warmest months is about 84°. In the south the east Sunda Islands are far enough from the equator to show a similar, but much smaller, increase in range, the monthly means at Koepang, Timor, ranging from 77° to 82°.

Health resorts are fewer than the mountainous nature of

the islands might suggest; temperature certainly decreases with height, an advantage won at the cost of very heavy rainfall and high humidity. But a few sheltered plateaux offer a change from the sultry hot-house climate at sea-level, and some stations have local advantages such as cool mountain-breezes.

Föhn winds occur in the lee of some of the very rainy mountain-ranges. Such is the Bohorok along the north-east of the backbone of Sumatra; the usual warmth of föhn winds is not prominent here, but the relative humidity falls so much that crops are sometimes damaged.

Representative data are:

			Mean Temperature									
			Warmest month				*Coolest month*					
	Lat.	*Alt., feet*	*Month*	*Daily max.*	*Daily min.*	*Daily range*	*Month*	*Daily max.*	*Daily min.*	*Daily range*	*Annual range*	*Absolute extremes*
Phu Lien (Haiphong) .	20·5 N.	377	83	89	78	11	62	69	57	12	21	107, 43
Bangkok .	13·7 N.	14	87	97	76	21	78	89	67	22	9	106, 52
Sandakan .	5·8 N.	105	82	89	75	14	79	85	74	11	3	99, 70
Penang . .	5·3 N.	17	83	92	74	18	81	89	73	16	2	98, 65
Singapore .	1·3 N.	7	81	86	77	9	78	85	74	11	3	97, 66
Manado . .	0·5 N.	5	81	89	73	16	79	85	73	12	2	97, 63
Pontianak .	0°	10	81	88	75	13	79	85	74	11	2	94, 68
Jakarta . .	6·2 S.	26	79	87	75	12	78	84	74	10	1	96, 66
Pasaruan .	7·5 S.	16	83	90	75	15	79	87	70	17	4	96, 58
Port Moresby .	9·5 S.	126	83	90	76	14	77	82	73	9	6	98, 64
Koepang. .	10·2 S.	148	82	92	74	18	77	87	69	18	5	101, 60

Rainfall[1]

This region is the largest area on the globe with rainfall of 100 inches and more. The islands enjoy soft moist air nearly all the year; the skies are clear at night, and bright white cumulus clouds appear in the forenoon, often to develop into formidable masses of thundery cumulo-nimbus in the afternoon. In the great mountain-ranges of Sumatra and Java, Borneo and New Guinea, the annual means exceed 150 inches; the driest districts, with less than 40 inches, are small and well-sheltered rain-shadows in the interior of Thailand (Siam) and in some of the islands, most of them in the east Sunda group. Between these extremes the large lowland areas average between 80 and 120 inches.

[1] Much of this section is based on Boerema, J., *Regenval in Nederlandsch-Indie.* Weltevreden, 1925.

In these low latitudes the rains might be expected to be heaviest in the intertropical convergence, which would give two pronounced rainy seasons and two dry seasons near the equator, but that régime is not common. The east coasts and ranges of Indo-China and the Philippine Islands in the north of the region get their heaviest rains in autumn when the NE. monsoon is blustering south against the retreating SW. monsoon; typhoons add much to the totals in that season. In the months of fully-established monsoons the rainfall is far less and may decrease on lee coasts to form a dry season of a month or two. In the south the southerly monsoon from Australia has a strong effect, giving a distinctly dry season in parts of the east Sunda Islands in the months June to September. But local orographic influence is powerful everywhere, and on most coasts the rainiest season is that in which a moist monsoon blows onshore to meet a mountain-range, and the driest is when the wind is offshore. Hence the two sides of a small island may have their corresponding seasons in different parts of the year and similarly the two sides of even a narrow channel. But in most cases the difference is mainly in the amount of rain in the drier season, without a complete reversal of régime. In view of the great diversity a short account of the rainfall of some important islands is given below. New Guinea is treated on pages 224–6.

The rainfall is very variable from year to year as is usual in the tropics, but even the dry years are seldom seriously deficient for agriculture in these well-watered islands. Manila has had 80 inches in August (mean 24 inches). Representative annual extremes are:

YEARLY RAINFALL

	Mean	*Highest record*	*Lowest record*
Hanoi	70	108	50
Singapore	95	136	58
Jakarta	71	97	46
Manila	96	154	38
Makassar	112	165	53

The rain is of the usual tropical types, frontal in the intertropical convergence, convectional, and orographic. Most of it falls with great intensity; many stations in the more rainy districts have had 12 inches in 24 hours, and much higher

records are not uncommon, rising to 24 inches at Phu Lien (Tonkin) and 46 inches at Baguio (Philippine Islands). An exception is the crachin of lower Tonkin, Indo-China, a persistent drizzle during the NE. monsoon in February and March such as is common in south China. Orographic rain

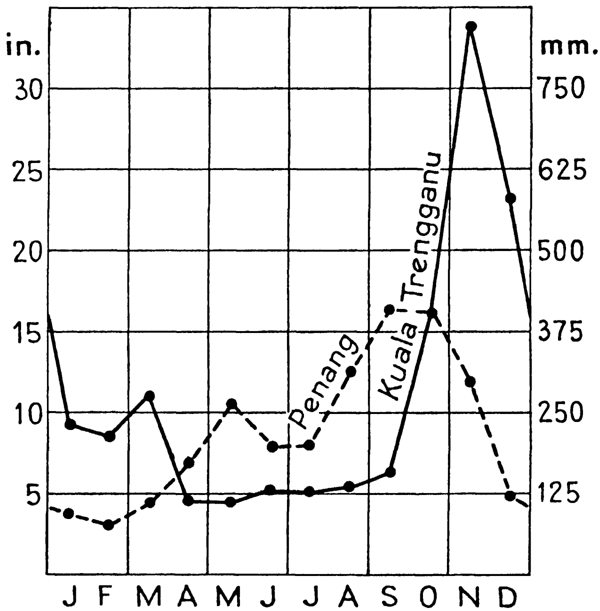


FIG. 78. Mean monthly rainfall.

often falls in long unbroken spells on windward coasts backed by mountains.

Thunder is very frequent in Sumatra and west Java; Buitenzorg records it on 322 days a year, which must be almost a record for the whole world; but many stations have much lower means, Jakarta (Batavia) 136 days, Surabaya 73, Singapore 41, and Manado (Celebes) only 35; Phu Lien (Tonkin) has 150.

The skies are much brighter than the large rainfalls might suggest, much more sunny than in most of the zones of the westerlies with less than a quarter of the rainfall; in most districts, as in much of the tropics, the rain is extremely heavy but is soon over; Jakarta gets all its 71 inches of rain in 357 hours

(Potsdam, Germany, 23 inches in 657 hours). The mean sunshine records are notably high in relation to the rainfall:

	Mean annual rainfall	*Mean annual sunshine (hours)*
Kuala Lumpur . . .	94	2,179
Jakarta	71	2,326
Makassar	112	2,849
Koepang	57	3,072

Malaya. The rainfall is very large, between 80 and 120 inches except in small sheltered areas, well distributed over the year; no season is really dry, the driest month having a mean more than 3 inches nearly everywhere. Most of the peninsula, especially the east side, gets its heaviest rain and worst weather in the months September to December from frontal disturbances as the NE. monsoon ousts the SW.; the much less vigorous advance of the latter gives a secondary, but small, maximum. The period of full SW. monsoon is the driest on the east (Fig. 78, Kuala Trengganu), that of full NE. monsoon on the west of the peninsula (Penang).

Representative stations are:

MALAY PENINSULA, MEAN RAINFALL

	Alt. feet	*J.*	*F.*	*M.*	*A.*	*M.*	*J.*	*J.*	*A.*	*S.*	*O.*	*N.*	*D.*	*Year*
Penang .	17	3·7	*3·1*	5·6	7·4	**10·7**	7·6	*7·4*	11·5	15·7	**16·9**	11·9	5·8	107·6
Kuala Lumpur .	190	*6·5*	6·6	8·7	**10·7**	8·3	5·0	*4·2*	6·2	7·4	**10·9**	10·1	9·6	94·0
Kuala Trengganu	105	9·3	*8·4*	**11·0**	4·6	*4·6*	5·2	5·0	5·4	6·3	16·1	**33·7**	23·2	132·8

Java. The amounts and régimes of the rainfall differ greatly. The mountains get very large totals, the means exceeding 160 inches on windward slopes; lee slopes have much less. A more general difference is between the west half of the island which, being nearer the equator, tends to have good rains all the year with no marked dry season, and the east which belongs rather to the east Sunda Islands and has less rain and a pronounced dry season in the months July to October; differences between neighbouring places due to exposure and altitude, large everywhere, are specially prominent in the east (Pakudo and Asembagus below).

Representative stations are:

JAVA, MEAN RAINFALL

	Alt. feet	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Jakarta (Batavia)[1]	26	11·7	**12·2**	8·4	5·6	4·3	3·6	2·5	*1·7*	2·7	4·5	5·7	7·9	70·8
Buitenzorg[2] . .	787	**16·7**	16·6	15·2	15·9	13·7	10·6	9·6	*9·4*	12·9	16·5	16·1	13·3	166·1
Pangerango[3] .	9,918	19·3	**22·4**	15·0	12·7	7·3	4·4	*3·3*	4·4	5·7	9·9	14·4	17·8	136·0
Pakudo[4] . .	2,428	**18·8**	17·7	15·8	*10·3*	14·1	13·9	14·2	**15·5**	*8·8*	9·3	11·9	15·6	166·1
Asembagus[5] .	131	7·6	**7·9**	5·6	2·3	2·1	1·5	1·1	<*0·1*	0·2	0·5	1·9	5·3	35·7
Surabaya[6] . .	203	**12·4**	11·7	10·5	7·0	4·3	3·4	1·9	0·6	*0·6*	1·5	4·7	9·9	68·5
Koepang[7] . .	148	**15·3**	14·4	8·7	2·5	1·1	0·4	0·2	*0·1*	0·1	0·7	3·5	9·7	56·7

[1] North coast, west end.
[2] North slope of mountains, west end of island.
[3] South slope of mountains, west end of island.
[4] South-east slope of mountain, east end of island.
[5] North coast, east end.
[6] North coast, near east end.
[7] Timor, north coast.

In the east Sunda Islands the rainfall decreases eastward to less than 40 inches in the driest districts; the dry season is longer and in most islands 1 or 2 months at least are almost rainless; a representative station, Koepang in table above, has only 2·6 inches in the 6 months May to October. This is the only part of Indonesia with a prominent dry season.

Borneo. The island lies astride the equator, and most of it has heavy rain all the year, totals exceeding 100 inches in the middle and north, 80 to 100 inches in the lowlands of the south and east, and 160 inches in the mountains. There is no really dry season, the driest months, July, August, and September, even on the south coast where a drier season may be distinguished, having nearly 4 inches each.

Representative data are:

BORNEO, MEAN RAINFALL

	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.	Year
Kuching (Sarawak)[1] . .	**26·4**	25·4	9·9	10·2	8·9	8·9	4·7	8·7	*7·9*	9·7	13·8	25·2	159·4
Jesselton[2] .	5·5	3·1	*3·0*	5·2	9·7	**11·6**	7·9	9·9	12·6	**12·9**	11·3	9·5	102·5
Sandakan[3] .	**19·0**	10·9	8·6	*4·5*	6·2	7·4	6·7	7·9	9·3	10·2	14·5	18·5	123·7
Banjermasin[4] .	**12·8**	11·9	11·7	8·7	6·3	5·7	3·8	*3·4*	3·9	5·3	8·5	12·6	94·6
Balik Papan[5] .	8·1	7·1	**9·3**	7·3	8·5	7·4	6·8	6·3	*5·2*	5·5	6·4	7·8	85·7

[1] North coast, west end.
[2] North coast, east end.
[3] North-east coast.
[4] South coast.
[5] South-east coast.

Celebes. The average rainfall amounts to about 100 inches, but exceeds 160 inches on parts of the mountains and coasts, and is only 40 to 80 inches in the driest districts. Of the many régimes, which depend on exposure of the many sides of the island to the monsoons, three may be mentioned. The north coast of the north peninsula (Manado in table below) has its very rainy season in November to April in the northerly monsoon, but the driest months, August and September, have

more than 3 inches each. The west coast (Makassar) also has pronounced rains in November to April, the northerly monsoon setting onshore here from the west, but June to October is a distinctly dry season, this being a lee coast in the southerly monsoon; Paloe, lat. 1° S. on this same coast, has the lowest annual mean in Celebes, 21 inches; it is at the head of a long narrow gulf well shadowed by mountainous coasts, and also has wider shelter from Borneo on the west and its own island on the east. The south-east (Kendari) gets its heavy rains from the southerly monsoon in December to July, and August to November is a fairly dry season.

Representative stations are:

CELEBES, MEAN RAINFALL

	Alt. feet	*J.*	*F.*	*M.*	*A.*	*M.*	*J.*	*J.*	*A.*	*S.*	*O.*	*N.*	*D.*	*Year*
Manado .	5	**18·3**	14·1	12·0	7·8	6·3	6·4	4·7	3·8	*3·4*	4·8	8·6	14·6	104·8
Makassar .	13	**27·0**	21·1	16·7	5·9	3·5	2·9	1·4	*0·4*	0·6	1·7	7·0	24·0	112·2
Kendari	33	**8·4**	8·3	7·7	7·4	8·4	7·5	5·4	2·8	1·3	*0·9*	3·0	7·4	68·3

Ceram. This small island shows an interesting contrast in régimes between the north coast exposed to the northerly monsoon, and the south exposed to the southerly.

Representative stations are:

CERAM, MEAN RAINFALL

	J.	*F.*	*M.*	*A.*	*M.*	*J.*	*J.*	*A.*	*S.*	*O.*	*N.*	*D.*	*Year*
Wahai, N. coast .	11·4	**15·1**	12·6	8·1	6·3	4·9	4·2	3·5	*3·4*	3·7	4·4	7·7	85·3
Amahai, S. coast .	4·4	4·3	5·6	8·3	14·2	15·6	**17·9**	15·0	8·5	5·5	4·2	*4·1*	107·6
Amboina, off S. coast	5·0	4·7	5·3	11·0	20·3	**25·1**	23·7	15·8	9·5	6·1	*4·5*	5·2	136·1

Philippine Islands, Indo-China. In the north of the region under consideration the NE. monsoon is strong and humid and gives a large orographic rainfall to mountainous coasts facing it. Such is the east of the Philippine Islands which gets most of its rainfall, exceeding 120 inches a year in some parts, in winter, with means over 20 inches in the rainiest month; but summer is by no means a dry season. The seasons are reversed in the west, which also has very large totals, nearly all brought by the SW. monsoon in summer; winter, January to March, is an almost dry season. The mountainous interior has enormous totals, Baguio 183 inches a year, nearly all in the SW. monsoon which gives about 40 inches in July and in August (July 1911 had the extraordinary record of 133 inches); winter is almost rainless.

In Indo-China also the east coast gets a large rainfall, most

districts more than 80 inches, with a marked maximum in autumn and early winter (typhoons contributing largely), and a fairly dry season in February and March. But in south-east Asia we have to cross Thailand (Siam) and Tenasserim to reach the coast facing the SW. monsoon of the Bay of Bengal, which gives extremely heavy rain in summer; winter is an almost dry season. The mean annual total here exceeds 150 inches.

The lowland plains of Siam and the west of Indo-China are sheltered, so that their total rainfall is only 40 to 80 inches. It is brought by the SW. monsoon, May to November being the rainy season (with means for some months exceeding 12 inches). Winter is a pronounced dry season, almost rainless. The hills along the coast of south-east Siam and south-west Cambodia face the SW. monsoon and have the heaviest rainfall, more than 200 inches a year, among the highest totals in south-east Asia.

Representative data are on pp. 218 and 225.

New Guinea, 1,500 miles long, is large and varied enough to claim separate description; it has extensive plains almost at sea-level clothed with equatorial forest, and at the other extreme large areas above 5,000 feet in the ranges which fill much of the interior, and snow is frequent on the mountain tops. The S. monsoon blows from SE. and E. from May to November, the N. monsoon from NW. (NE. on the north coasts) from December to March. The west of the island is almost on the equator, and has equatorial conditions all the year; round and west of Geelvink Bay the annual rainfall exceeds 100 inches, and even the driest month, October, has more than 4 inches, at many stations more than 8. The mean annual range of temperature is very small, only 1·4° at Manokwari.

The rest of the island trends WNW.–ESE., and the driest season is when the southerly monsoon is blowing along the grain of the land. But even July and August have more than 2 inches each, and in most parts probably more than 4 inches; the yearly totals are very large, exceeding 100 and up to 200 inches on the coasts and low plains, and very much more in the mountains. But local variations are many in both the amount and the season of rain. In some cases the explanation

MEAN RAINFALL

	Alt. feet	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Philippine Islands														
Paracale[1]	16	17·8	11·7	7·9	*4·1*	6·9	8·6	**11·2**	*6·7*	9·7	**20·2**	19·8	19·6	144·5
Manila[2]	47	0·6	0·6	*0·5*	0·8	7·7	12·3	19·5	**24·0**	13·4	7·7	7·1	2·1	96·3
Baguio[3]	4,954	1·0	*0·9*	1·9	4·4	15·7	19·3	40·1	**47·1**	31·1	14·8	3·5	1·8	183·0
Indo-China														
Hanoi[4]	46	*1·0*	1·3	1·9	3·6	8·4	10·4	11·1	**13·9**	10·5	4·3	2·0	1·2	69·9
Hué[5]	20	6·9	3·0	4·6	*2·0*	5·0	3·0	2·8	4·5	13·6	23·5	**29·9**	15·5	114·5
Saigon[6]	36	0·7	*0·1*	0·7	1·7	8·0	13·3	12·0	10·3	**13·7**	11·0	4·7	2·7	79·2
Pnom-penh[7]	43	*0·1*	0·6	1·9	3·8	5·0	6·0	5·9	6·4	9·0	**9·6**	6·8	2·0	57·5
Thailand (Siam)														
Bangkok[8]	14	0·3	0·8	1·4	2·3	7·8	6·3	6·3	6·9	**12·0**	8·1	2·6	*0·2*	55·0
Tenasserim														
Mergui[9]	66	0·9	2·0	3·1	5·3	16·9	29·4	**31·5**	29·2	26·4	12·1	3·7	*0·7*	161·2

[1] East coast.
[2] West coast.
[3] West, interior.
[4] Tonkin, coast.
[5] Annam, east coastal plain.
[6] Cochin China, south-east coast.
[7] Cambodia, interior.
[8] Near coast.
[9] West coast.

is the trend of the ranges, as on the north of Huon Gulf where the rainiest season is that of the S. monsoon which strikes the mountains almost at right angles; the rainfall exceeds 250 inches, and means up to 33 inches a month are reported for May, June, and July; January and February are least rainy, but still have more than 8 inches each.

The shores of the Gulf of Papua have varied conditions. The neighbourhood of Port Moresby has a low rainfall, only about 40 inches a year; the S. monsoon is dry, the months June to September having about 1 inch each, and December to March is a pronounced rainy season. Kikori, however, on the north-east shore of the gulf, has 230 inches a year, most in May–June and September–October; December with 11 inches has least. Daru, on the other hand, 150 miles south of Kikori and near the mouth of the Fly River, with an annual total 83 inches, has most in January to May, April being the rainiest month, and least in July to October, a relatively dry season with less than 3 inches a month.

Representative data are:

NEW GUINEA, MEAN RAINFALL

	Alt. feet	*J.*	*F.*	*M.*	*A.*	*M.*	*J.*	*J.*	*A.*	*S.*	*O.*	*N.*	*D.*	*Year*
Daru .	25	11·9	10·4	12·5	**12·6**	9·4	3·8	3·0	2·2	*1·8*	2·3	4·6	8·1	82·6
Port Moresby	126	7·0	**7·6**	6·7	4·2	2·5	1·3	1·1	*0·7*	1·0	1·4	1·9	4·4	39·8
Madang .	20	12·1	11·9	14·9	**16·9**	15·1	10·8	7·6	*4·8*	5·3	10·0	13·3	14·5	137·2

The hot air is heavily charged with vapour, and massive cumulus cloud covers the sky during much of the day, especially in the mountains. It is hottest in the southern summer, when the mean monthly temperature is about 82° near sea-level; the coolest 'winter' is in Australian Papua, where the mean of July and August, the coolest months, is about 78°. In the rest of the island the mean near sea-level is a little above 80° in every month.

TYPHOONS

Many of the largest originate near the Caroline Islands (Fig. 79), but some over the South China Sea. They belong to the same class as hurricanes in the West Indies region and cyclones in the Bay of Bengal, and their meteorology and characteristics are similar.

It will be seen that some typhoons travel almost due west

and reach the coasts of Indo-China and China, and others recurve on a parabolic course, following more or less closely the Kuro siwo; many of the latter degenerate into ordinary extra-tropical cyclones of the westerlies. The Philippine Islands are unfortunate in lying right in the track of a large

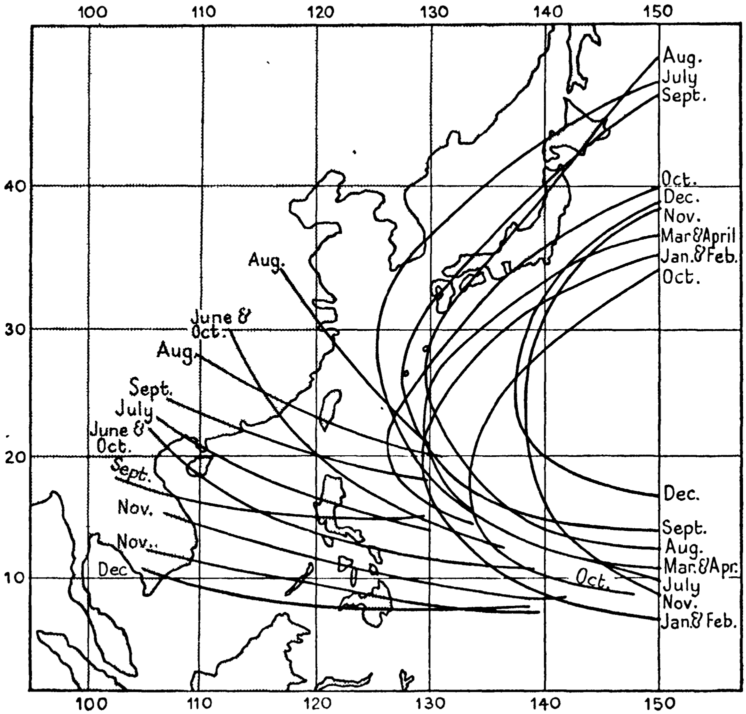


FIG. 79. Generalized tracks of typhoons.

proportion of the disturbances during their most violent stages; the lowest atmospheric pressure ever recorded at sea-level on the globe, 887 mb. (26·19 inches), was in a typhoon 400 miles east of Luzon. Fig. 79 indicates that typhoons tend to originate and remain farther south in the southern summer. But they are rarely found within 5° of the equator, so that Indonesia is almost outside their range, the only exceptions being the extreme north of Borneo and of Malaya; the south of Timor, east Sunda Islands, is occasionally visited by 'Willy-willies', corresponding cyclonic storms of the region north-west of Australia (p. 550). But it must be remembered that here as

in other parts of the globe cyclones are erratic both in speed and direction of movement; the tracks shown in Fig. 79 are much generalized. The following extract from the report of the Weather Bureau of the Philippine Islands on a typhoon in December 1918 illustrates this:

From the fact that on December 18th to 20th there was a marked increase in the strength of the NE. wind at the Island of Guam it is inferred that the typhoon was already developed, though it must have been centred more than 400 miles to the southward. The important indications at Yap were the changes in the direction of the wind and the break in the weather. During the 17th to the 19th the wind was NE., on the 20th it had veered to ENE., then to E. in the early hours of the 21st, and after sunrise to SE. With these wind changes the sky became overcast, with rain squalls, and during the 20th nearly 2 inches of rain fell. . . . By the morning of the 22nd the NE. wind over the Philippine Islands was backing N. and NW., and at 9.30 a.m. a warning was issued 'There is a typhoon over the Pacific about half-way between the Western Carolinas and Mindanao, probably moving WbN'. . . . The typhoon now became much more pronounced, and successive reports showed that until 6 a.m. on the 24th the core of the system was following a north-westerly course, and having reached 14° N., 128° E., the authorities were convinced that it was curving away to N. and NE., and would soon cease to affect the islands, and before noon on the 24th they did not hesitate to order the typhoon warnings to be lowered. However, suddenly, and without any definite premonitory signs, the NW. advance was arrested, and the afternoon observations showed that the centre was moving WSW., and to the surprise of the authorities it maintained this unusual course across the middle Philippine Islands and the South China Sea to the neighbourhood of Saigon before the close of the month. The lowest barometer readings were registered at about noon on the 25th, 28·50 inches at Magallanes, 4 miles from the centre, and 28·52 inches at Sorsogon, 3 miles from the centre. On the 22nd the rate of progress of the system was about 11 miles an hour; next day . . . it slowed down to only 3½ to 4 miles. Then after curving to WSW. it advanced at 12 miles until the morning of the 26th when the rate was again reduced to about 9½ miles during the passage across the South China Sea. . . . The area of destruction, while the storm was raging in or near south-eastern Luzon, was about 80 or 100 miles in diameter. . . . The wreck of the steamer *Quantico* took place on the evening of the 25th on the north coast of Tablas Island; 21 lives were lost. . . . At Romblon,

nearly all the houses, even those of strong materials, suffered. . . . Many big trees were uprooted. Light trees like bananas were completely destroyed. The tower of the church was blown down. There was no absolute calm (eye of the storm), but relative calm was observed for about one hour, with light winds, force 1 or 2.

The frequency of typhoons is given on page 205. But such data are not exact owing to the lack of a precise definition of typhoon, and also the possibility of storms not being observed, or being counted more than once.

CHAPTER XXIII
THE HEART OF ASIA

WITH a width of about 500 miles, narrower or wider as the enclosing mountains approach more or less closely, a vast arid tract extends for 2,000 miles from the Pamirs ENE. to the Khingan Mountains. It is really a great basin, or rather a series of basins enclosed on all sides, especially the west, by much higher land; but the average elevation above the sea is about 3,000 feet, so that the term plateau is not inapplicable, and many mountain-ranges intersect the region. The tops only of the ranges now project above the deserts of gravel and sand, the products of subaerial denudation which bury the lower parts of the mountains from which they were derived.

Central Asia is often classed as a continuation of the deserts of north Africa and Arabia. It resembles them in aridity and in the great summer heat, but by no means in the winter conditions. In winter the heart of Asia is under the great cushion of dense air that collects over the cold continent, giving the highest atmospheric pressure (corrected to sea-level) on the earth's surface. Calms and gently outflowing winds prevail in the middle of the high-pressure region, and there can be very little precipitation. But in the east blustering NW. winds, dry and dusty, descend over China. In spring the heated land throws off its burden of air, and the transition to the low-pressure conditions of summer is a stormy period, which is described later. The heat of summer generates low pressures and the summer monsoon blows inward from E., N., and W.; under more advantageous conditions of relief a certain amount of precipitation would probably be received,

despite the distance from the sea. But the deserts are surrounded by mountains; those on the south-west of the Takla Makan are among the highest ranges on the globe. Most of the Indian monsoon is stopped by the wall of the Himalayas, a barrier 5 miles high; in the east a small part makes its way into Tibet, but it must still cross 700 miles of plateau, elevated 3 miles above the sea and ribbed by numerous ranges, before reaching the Takla Makan. Probably none of it travels so far north as to make the descent into this inland basin, and even if it succeeded in doing so it would be so much warmed adiabatically as to be very dry. Similarly on the north and west the mountain-barrier, though lower, suffices to ward off rain. Only in the east do moist winds penetrate, and a belt of good steppe land about 70 miles wide borders the south-east of the Gobi. The sea is only 350 miles away, and the SE. monsoon still contains enough moisture to make agriculture possible with the help of irrigation. The north edge of Mongolia also is by no means desert, the rainfall maintaining abundant grass in places; Ulan Bator (Urga) has 7 inches of precipitation a year.

The mean precipitation is probably under 2 inches a year in the middle of the deserts; in the east it is somewhat heavier and may approach 10 inches in favoured localities. But even 2 inches must not be expected in the deserts every year; many years have far less, and the balance is restored by a violent cloudburst at long intervals. Traces of overwhelming floods may be seen in the deep channels, now dry, which the torrents excavated. There are no long series of records, but the available data show that the total precipitation is made up of winter snow as well as summer rain. The annual mean at Kashgar is 4 inches, of which over two-thirds is received in spring and autumn. Yarkand had half an inch in the single year a rain-gauge was maintained. A traveller who stayed at Lukchun near Turfan for 10 months reports that it rained 5 or 6 times, and snowed 3 times, the snow disappearing the day after it fell. Urga has an annual mean 7 inches; July and August are the rainiest months. The country some distance west of the edge of the plateau is evidently within reach of the rain of the SE. monsoon, and it also has a little snow in winter; records from the tract near the north of the great loop of the Hoang Hoare:

	Alt. ft.	*Mean an. precip.*	*Mean number of days with precip.*
Saratsi (40° 36′ N., 110° 30′ E.)	1025	13·8	39
Santaoho (40° 15′ N., 106° 42′ E.)	—	—	29

A large factor in the meteorology is the latitude, for central Asia lies between 37° and 50° N. and therefore has a large seasonal change of insolation. The annual range of temperature is very large indeed. It is instructive to recall for comparison the conditions of the Sahara. There the desert, far from being confined to the interior of the continent, reaches the sea on the west, north, and east, and mountains are of but minor importance in causing aridity. Thanks to the low latitude winter is not cold, for even in the north of the Sahara the January mean is 60°. As in almost all deserts the range is considerable, but not nearly so large as in central Asia.

The air in the Takla Makan is dry; Sven Hedin recorded mean relative humidity 28 per cent. in May, 69 per cent. in December. The mean humidity at Lukchun at 1300 in summer was 20 per cent. The sky seems to be somewhat more cloudy than in the Sahara.

The summers are very hot, the sunshine pouring down in the long days through the dry air. Satisfactory records are wanting, but some available data are:

	No. of years' obs.	*Alt. (approx.) feet*	*January Mean temp.*	*January Abs. min.*	*July Mean temp.*	*July Abs. max.*
Kashgar .	3	4,296	23	−13	80	—
Yarkand .	1	4,120	21	2	82	103
Lukchun .	2	−100	13	−5	91	118
Uliassutai .	1·5	5,365	−10	−40	60	94
Ulan Bator (Urga)	7	3,445	−11	−46	63	97

Uliassutai and Urga are comparatively cool thanks to their higher latitude; the position of Lukchun below sea-level explains its excessive heat, but its figures are eclipsed by reports of Turfan, near which the depression sinks to 300 feet below sea-level. Domestic animals, even camels, cannot live through the summer, and have to be driven up the mountains. Ellsworth Huntington tells us that 'according to the Chinese, the summer is so hot that during the day the birds all gather in the shade of the trees beside the rivers. If one of them flies up, he is scorched to a cinder and falls sizzling into the water.

Another Chinese yarn affirms that the heat is so great that after blowing on your rice to cool it, you must ply your chopsticks as fast as possible. If you do not, the rice will become hot again and burn you!' During the heat of the day the natives retire to underground chambers. Younghusband, speaking of a journey between the Tien Shan and the Altai,

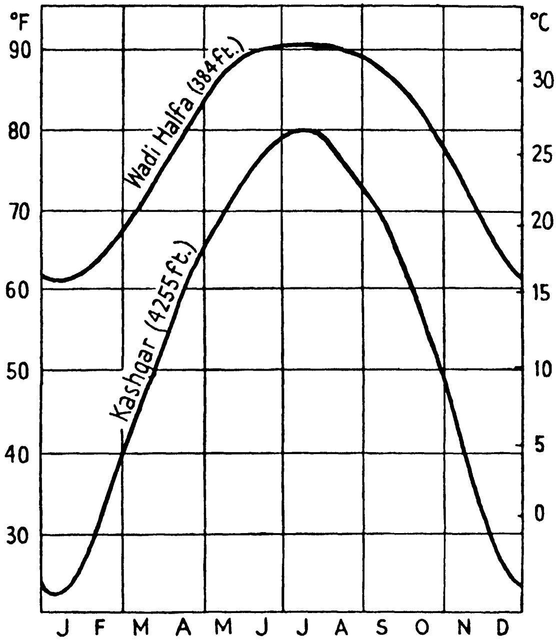


FIG. 80. Mean temperatures.

says: 'The heat was intense, for the wind blew off the heated gravel as from a furnace, and I used to hold up my hand to protect my face in the same way as one would in front of a fire.'

In summer central Asia resembles the Sahara; the contrast in winter is shown in Fig. 80. Frost is indeed by no means unknown in the north of the Sahara on winter nights, but the mean January temperature (sea-level) is above 50°. In the deserts of central Asia the mean for the same month is considerably below freezing-point. Standing water and small rivers are frozen throughout the winter months and the natives bring home their water-supply in the form of blocks

of ice. The thermometer rarely rises above freezing-point even at midday, and at Tarim Jangiköl, 2,890 feet above the sea, Sven Hedin reports the mean daily maximum temperature, during the January he stayed there, as 26°. The monthly mean for January was 9°, and the lowest reading he recorded during his winter's stay was −14°. In the middle of the Takla Makan a minimum of −25° was observed in the beginning of January, and on 2 January the maximum was only 8°. Other data are in the table on page 231.

In the dry still air these low temperatures are more endurable than might be expected. Ellsworth Huntington says he could sleep comfortably under a sheepskin in the open air with a temperature of −6°. A pronounced inversion of temperature is usual, as is natural in a basin in these latitudes surrounded by very high land, some of it capped with snow and ice; temperature increases up to about 1,000 feet above the low ground.

The cold winter lasts from the end of November till the end of March. The west of the Tarim Basin has 3 months, Urga 6 months, with a mean temperature below freezing-point. The transition to summer is accomplished by May, so that spring is a time of extraordinarily rapid increase in temperature. At Tarim Jangiköl the mean when Sven Hedin was there was 17° in February, 40° in March, 55° in April, 69° in May. The difference between February and March was larger than between January and July in England.

The mean daily range is very large throughout the year, about 36° near the Tarim, and 24° at Lukchun in winter, 30° in summer, but much larger ranges, many over 70°, have been noted on some days. The annual range reaches remarkable figures, 57° at Kashgar, 78° at Lukchun, 74° at Urga, and 70° at Uliassutai.

Early in spring violent ENE. winds set in, to continue by day till the end of summer. Blowing with gale force they carry clouds of dust swept up from the desert, which darken the air and make life miserable. They are known as karaburan, 'black storms'. The sand they drive along is one important cause of the rapid changes in the courses of the rivers through the desert.

The daily winds [in the Gobi] were often extremely disagreeable. It was with the greatest difficulty that we could keep our tents from being blown down, and everything used to become impregnated with the sand, which found its way everywhere, and occasionally we had to give up our march because the camels could not make any head against the violence of the wind (YOUNGHUSBAND).

The coarse particles are not carried beyond the limits of the desert, but the lighter dust spreads far outside, and gives a characteristic haze on summer days. The fine dust gradually sinks to the ground and in the course of long ages has built up the deep and extensive deposits of loess. Ellsworth Huntington describes the scenery on the mountain slopes about 14,000 feet above the sea on the south-west of the Tarim basin:

Instead of the boulders and rough hollows which one usually sees in moraines, these presented surprisingly soft outlines, for they had been deeply buried in loess deposited from the atmosphere. The loess was covered with thick grass, full, as we soon saw, of countless Alpine flowers and dotted with sleek flocks of sheep and herds of cattle. . . . Our gaze went out far beyond [the lower mountains] to where the last low hills gave place to a strange yellow band. It seemed at first to be the sandy desert of the heart of Asia; but during the two hours of our stay on the pass it expanded and rose, and we then knew it for the inevitable dust-haze which shrouds the country more than half the year.

The dust-storms rage by day only. At night the desert air is usually calm. To quote from Younghusband's narrative:

The nights were often extremely beautiful, for the stars shone out with a magnificence I have never seen equalled even on the heights of the Himalayas. Venus was a resplendent object and it guided us over many a mile of that desert. The Milky Way, too, was so bright that it looked like a bright phosphorescent cloud, or a light cloud with the moon behind it. This clearness of the atmosphere was probably due to its being so remarkably dry. Everything became parched up and so charged with electricity that in opening out a sheepskin coat or a blanket, a loud crackling noise would be given out, accompanied by a sheet of fire. The temperature used to vary very considerably. Frosts continued to the end of May, but the days were often very hot, and were frequently hottest at nine or ten in the morning, for later on a strong wind would usually spring up, blowing sometimes with extreme violence till sunset.

Autumn and winter are free from dust-storms, and the clear, dry, invigorating air and pleasant temperature of the second half of September, October, and early November are described as forming an ideal climate.

The Takla Makan desert is surrounded by a ring of coarse gravel detritus which has been carried down from the mountains by the streams in their rapid course to the depression. The water of the smaller streams disappears rapidly into and percolates through the gravel, and comes to light again at a lower level when it meets finer deposits of sand and clay, and provides a fairly continuous zone of moisture and verdure. In the most favoured districts, with enough water to fill irrigation channels, gardens of unrivalled luxuriance produce the most luscious fruits, pears, apricots, grapes, melons. Agriculture depends in west Mongolia entirely, and in east Mongolia largely, on the water that seeps through in this way, or on the streams from the mountains, whose short courses through the desert are made still shorter by the demands of irrigation. Evaporation everywhere greatly exceeds precipitation, and most of the streams, which owe their origin to the rains and melting glaciers of the distant mountains, soon wither away in saline lakes. A belt of trees, reeds, and other undergrowth marks their course. The Tarim, Khotan Daria, and Charchan Daria alone succeed in extending their ribbons of verdure right across the desert.

The mountains enclosing the Tarim basin on the north are high enough to have much more precipitation than the floor of the depression; large areas of the Tien Shan are over 12,000 feet, and the highest point, Khan Tengri, attains about 23,600 feet. Precipitation is heavy and frequent on the north of the ranges, where few days in summer are rainless, and heavy cumulus usually hides the upper slopes; much snow falls in the winter half-year. Extensive snowfields feed many long valley-glaciers; the snow-line, not continuous, is at about 12,000 feet. The mean annual precipitation probably exceeds 30 inches above 10,000 feet. The highest altitudes are too rocky and barren, the cold too intense, and the snow often too deep, for even nomad occupation. Below 10,000 feet the winter snow is heavier than above, and a belt of forest clothes

the zone between about 10,000 feet and 8,000 feet, below which the aridity increases rapidly. But the summer rainfall is heavier above than below 10,000 feet, and between 10,000 and 14,000 feet produces rich pasture; much of it remains free of snow in winter, and is a favourite pasturing ground for the Kirghiz.

For the Pamirs some years' meteorological observations are available from Pamirski Post, a Russian station on the Murghab River, 12,000 feet above the sea. The precipitation is extremely scanty, only 2 inches a year (Leh in the Indus valley has 3 inches); probably it is a little more at less elevations, for the lower valleys get much snow; the mountain-ridges get but little, and have no glaciers. Pamirski Post has the steppe régime of rainfall with most in late spring and early summer. The air is remarkably dry (mean relative humidity about 40 per cent. in summer, 60 in winter) and clear except when hazy with dust. The rays of the sun are very powerful even in winter, when the shade temperature is far below freezing-point. The diurnal range of temperature is very large. The mean temperature in January is 1°, in July 56°, the extreme readings recorded −52° and 82°. Strong SW. winds blow up the valleys by day throughout the year.

CHAPTER XXIV

TIBET

NOT only the climate but the whole life of Tibet is essentially conditioned by the great elevation. The plateau is an enormous block, more than 14,000 feet above the sea except in the valley-bottoms of the east. Its length is about 1,200 miles, width 400 miles in the west and 600 miles in the east. It is walled on the south by the Himalayas, on the north by the Astin Tagh, the Kun Lun, and other ranges. The atmospheric pressure is only about half, in the highest parts rather less than half, that at sea-level, and visitors suffer from fatigue, shortness of breath, and mountain-sickness after any undue exertion in such rarefied air.

The highest part, the north-west, is known as the Chang (1 in Fig. 81), over 15,000 feet everywhere, and much of it

17,000 to 18,000 feet, considerably higher than the summit of Mont Blanc. It consists of a series of wide flat detritus-filled valleys with an east–west trend, separated by parallel ranges. Much of the surface is bare, in parts covered with salt which glistens so white in the intense sunshine that the natives who have to cross it wear dark spectacles. But many tracts have a fairly good plant-cover; trees do not grow, but grasses and

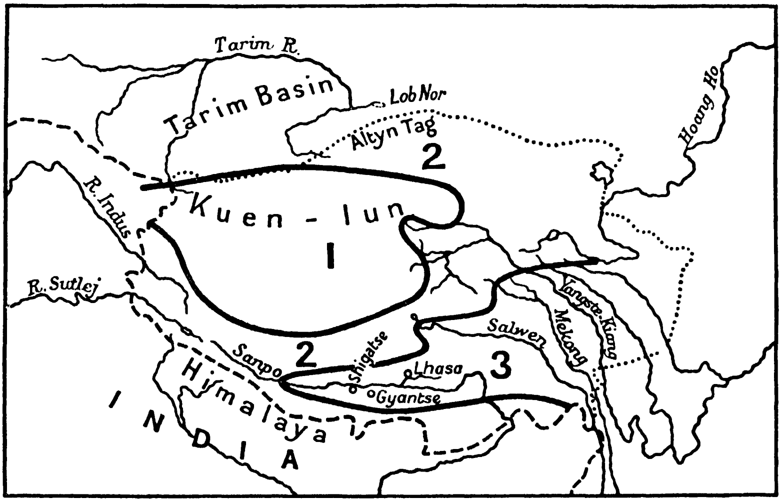


FIG. 81. Major climatic regions of Tibet.

other low herbs, few more than 3 inches high, are common, and their deep roots show how physiologically dry is the habitat. Antelopes and a few other species manage to live on the grass, but not even the hardy nomad natives take their flocks to these bleak uplands. It is of interest that flowering shrubs have been found in parts of Tibet as high as 19,000 feet, and butterflies up to 17,600 feet.

South of the Chang are the 'Upland Pastures', 13,000 to 15,000 feet (2 in Fig. 81), the summer resort of the Dokpa and their flocks, with abundance of excellent grass on the lower levels.

These general statements on altitude and vegetation probably give the most useful indication of the climate in the absence of reliable series of meteorological observations. Even isolated readings are few, taken by travellers on their journeys

or during stays of a few weeks, but they add valuable detail. The warmest month is August, but even in August frost is to be expected every night and a reading of 19° has been recorded. Thunderstorms give hail and snow not infrequently in summer, as well as rain, with bitterly cold squalls, but except during precipitation the air is remarkably clear, containing few dust or water particles, and the atmospheric pressure is only about 560 mb. (16·5 inches); consequently insolation is intense, but the air is cold; Sven Hedin recorded 147° on a black-bulb thermometer in the sunshine, while the air temperature in the shade was only about 55° (barometer 580 mb., 17·1 inches); the fall in temperature from day to night is large and rapid. Winter is exceedingly harsh; Bonvalot travelled through the region in the months December to March, and recorded −40° on 6 January. The same reading, −40°, was the lowest taken by Sven Hedin, in 35° N., 80° E.; on the previous day 'the night came down over the enormous snow-fields, biting cold. The temperature went down to the freezing-point of mercury (−37°). I had two candles and a nice fire in my tent as it was Christmas Eve. The next morning one pony lay dead and hard in his place among the rest.' A Russian party took observations for 15 months in the south-east of the Tsaidam salt-steppe, 36·2° N., 97·3° E., altitude 9,380 feet, which gave the mean temperature 9° in January, 63° in August, the extremes being −20° and 91°. In November the lakes on the high plateau freeze, Nam Tso early in December; Tsing Hai (Koko Nor), on the plateau but outside Tibet, is often frozen and Buddhists cross the ice to the holy island of Kiusu, but the numerous very salt lakes do not freeze. All the rivers are frozen except those of large volume in the south-east of Tibet at a lower altitude.

Strong winds blowing day after day in all seasons are mentioned in travellers' diaries as making the cold harder to bear than the thermometer readings might suggest; blizzards occur even in summer at these great heights. The general winds are from the west, veering to north in the afternoon before dying down in the evening.

The south-east of Tibet (3 in Fig. 81) is a much less inhospitable land than the high plateaux. It includes the upper valleys

of the Sanpo and the great rivers of south-east Asia, which are warm in summer and have enough water from rain and melting snow on the ranges for agriculture and forests; trees flourish up to 13,500 feet and travellers describe the pine forests in the valleys at about 12,500 feet. Wheat is grown to altitudes of 12,000 feet, and millet, maize, and rape are common crops; the Lhasa valley is very productive, having the advantage of extensive irrigation. The higher slopes get a good deal of snow, the melting of which is artificially hastened in spring by scattering stones and earth on its surface to absorb the strong insolation.

Standard climatological observations[1] have been made for four years at Lhasa, 12,240 feet, in the valley of a left-bank tributary of the Sanpo, and in this little-studied country they are of special interest, but their period is still too short to give reliable mean values in what appears to be a variable climate, the precipitation in particular being much larger than is probable. The mean atmospheric pressure for the year is 649 mb. (19·2 inches), the highest monthly mean 652 mb. (19·3 inches) in October, the lowest 645 mb. (19·1 inches) in June. The wind is always very light, and about half the observations are calms; the bold topography forces nearly all the winds to blow along the valley as easterlies or westerlies, and the ranges not only dominate the winds but help by their shelter to give remarkably high temperatures so that peach-trees are in bloom in the first days of April.

The mean temperature at Lhasa is 48°, the range 31° from 32° in January to 63° in June; the absolute extremes in 4 years were 6° and 84°. Temperature rises fast in spring (mean for April 49°, higher than for October, 48°), the lag of air temperature behind insolation being shorter than normal in this transparent atmosphere. June is the warmest month, temperature beginning to fall towards the end of the month under the heavy cloud and rain of the monsoon. In clear weather the diurnal range is large, hot days of intense sunshine being followed by cold nights, but the mean for the year, 25°, is not excessive for such a district. Frost occurs almost every night in the months November to March, but never in June to September.

[1] A. Lu, 'A Brief Survey of the Climate of Lhasa', *Q.J.R. Met. Soc.*, 1939.

The precipitation is notably large, the annual mean for 4 years being 63 inches (but the yearly totals ranged from 14·7 to 198·2 inches). The monsoon penetrates far up the great valleys (but cannot cross the high ranges or reach the lofty north-west), and brings the usual monsoonal weather; throughout July, August, and September the heavy cloud is in strong contrast to the almost cloudless blue of winter, and the rainfall, 26 inches in July, 18 inches in August, 7 inches in September, almost equalled that of Bombay in those months. Nearly all the rain is in the period May to September; most of it falls in heavy instability showers, often with thunder (in contrast to the little thunder in the Indian region). A few light snow-showers whiten even the valley-bottom occasionally in winter, but the snow soon melts. The mountain-ranges get more snow, but not a great depth, and the melt-water provides useful irrigation below in the growing season. The snow-line is remarkably high, 19,000 to 20,000 feet on the average; on the south face of the Himalayas it is down to 16,000 feet.

CHAPTER XXV

SOUTH-WEST ASIA

(TURKEY, SYRIA, LEBANON, ISRAEL, ARABIA, IRAQ, IRAN (PERSIA), AFGHANISTAN, BALUCHISTAN)

[Information on the general meteorology of this region will be found in Chapter XXX, tables of temperatures on p. 248, of winds on p. 259.]

In south-west Asia extreme continental conditions, both cold and hot and dry, approach closely to the shores of the Mediterranean, and the weather is subject to wide and sudden variations according as one of the continents or the warm humid Mediterranean gains the upper hand.

In winter most of south-west Asia is dominated by the high pressures of central Asia, a prominent extension of which covers Anatolia. The Mediterranean and Black Seas are regions of low pressure, but their direct influence does not extend very far inland. The general winds are NE., bringing cold dry continental polar air from the interior of Asia; but the low pressures of the Cyprus Sea and the Black Sea con-

trol the winds on the surrounding coasts, giving prevailing south-westerlies on the north littoral of Anatolia, northerlies on its south coast, southerlies in Syria and Israel. Most of the travelling Mediterranean depressions with their variable winds and weather do not make their way a great distance inland, but some are vigorous enough to advance far to the east, aided by the warmth and humidity of the Caspian Sea and Persian Gulf. Many of them, all in the winter half-year, follow a track over Syria, Iraq, Persia, and Afghanistan to the Plains of India, and their cold fronts give those lands most of their precipitation, which is not copious even on the mountains. In Arabia the parallel of 20° N. is the southward limit of their influence, the western highlands and the mountains of Oman getting some precipitation.

On the Mediterranean Sea and its coasts these depressions are the main weather-control in winter and give all the precipitation, which is moderate in amount, heavy only on some mountainous coasts. The rain is very variable from year to year, a serious consideration in a region which at best is semi-arid, with agriculture almost the only source of its livelihood. The first signs of the autumn rains are eagerly watched for; a late beginning or an early cessation in spring may be catastrophes. A local feature of importance is the warm indraught in front of depressions, the scirocco of Palestine and Syria, which is known in all seasons except summer, but is most prominent in spring and autumn, when the disturbances are vigorous, and the deserts of Arabia from which the air-mass is derived are already hot; the dry dusty air may have a temperature well over 100°, and the very sudden drop in the polar air behind the low-pressure trough is the more noticeable by contrast.

The whole region is liable to be swept by cold waves from the north behind large deep depressions. The advance of many of them can be traced clearly from their origin in central Europe or Russia to the Black Sea, the Levant and adjoining lands, and far south in Egypt. They naturally occur only in the cold months, and are severe when abnormally high pressures cover the Balkan Peninsula. E. and NE. winds of more than the usual velocity bring notably cold and dusty air from Asia, though the sky is cloudless.

Another effect of the depressions that pass eastward in spring is seen in the frequent thunderstorms of the north of Syria and Iraq where the hot arid steppes end abruptly against the mountains of the south-east of Anatolia which still bear their winter snows, giving strong temperature-contrasts.

The summer conditions are simpler and more uniform. West of Persia the main air-stream is W. and NW., between the Azores anticyclone and the low pressures of south Asia; Persia has northerlies, variable in direction and force; Arabia south of 20° S. is within the range of the SW. monsoon which gives the highlands of Yemen useful rains. The north coast of Anatolia is exceptional in having E. and NE. winds west of Cape Karembe, blowing to, and through, the windy Bosporus; strong onshore winds give the south-east coasts of the Black Sea heavy rain even in summer, though less than in winter. Depressions are few and the weather changes little from day to day. The coasts are cooled by the sea-breeze which blows regularly between about 0800 and 1800.

Turkey

Very different climates are included.

The north littoral of Anatolia. This is a well-watered region, the mountain-slopes in particular getting much precipitation, cloud, and moist air, from depressions on the Black Sea in autumn and winter, and a considerable amount from the onshore winds in spring and summer (Trabzon, Fig. 82). The winter half-year has variable winds (most between S. and W.) and unsettled weather as on the Mediterranean; the southerly winds in front of depressions are warmed by their descent from the plateau, but the strong northerlies in rear are often very cold; the mean temperature of February, the coldest month, at Trabzon is 44° (at Marseilles 43°); snow falls heavily at times, and the mountains are covered for about half the year, the highest ranges in the east most of the year.

In summer NW. winds are almost constant except for modifications due to topography and the alternating land- and sea-breezes. Unlike most of south-west Asia the south-east littoral of the Black Sea has useful rain in summer owing to the ranges behind the coast. The summer temperature (mean

for August, the warmest month, at Trabzon 74°) recalls the Mediterranean coast of north Italy, but the abundant moisture fosters a much richer vegetation on the narrow coastal lowland, where, with the common Mediterranean fruits, tea and tobacco flourish; good forest clothes the steep slopes. The advantages of the coast east of Sinop are increased by the shelter of the Caucasus Mountains, distant though they are (the absolute minimum temperature at Samsun is 20°, at

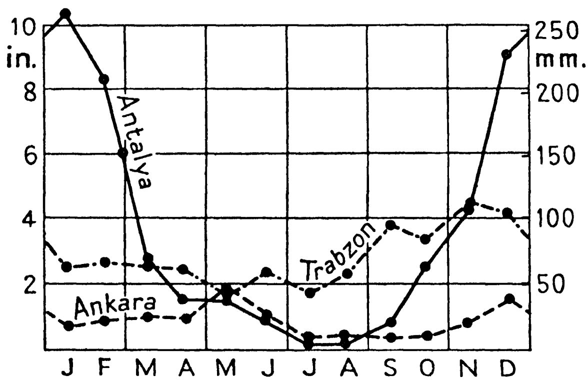


FIG. 82. Mean monthly precipitation.

Taganrog on the Sea of Azov −22°); the coast between Sinop and the Bosporus is more exposed to cold NE. winds, and moreover it does not enjoy such frequent föhn winds from the plateau; the summers are nearly rainless, and the vegetation has notably less than the average Mediterranean luxuriance; the olive does not flourish. The mean annual precipitation is as much as 100 inches on the littoral (more on the slopes facing north) in the east, and decreases westward but with large local irregularities.

The Plateau. From the north we rise through the forests of the coastal ranges to the plateau, most of the middle of which consists of shallow arid basins 2,000 to 4,000 feet above the sea, enclosed by higher ranges; the plateau rises and is better watered towards the east, where much of it exceeds 8,000 feet, with ranges above 10,000 feet (Mt. Ararat 17,000 feet). On the south it is rimmed by the Taurus and farther east by the Anti-Taurus and other ranges. The short journey from the north coast brings us to an entirely different land with

continental extremes and scanty precipitation, for the high pressures usual in winter ward off the genial influence of the surrounding seas and give cold, dry weather (yet the winter half-year is the period with most precipitation). The winds are usually north-easterly, strong, dry, and cold, from the steppes of south-east Russia, but sometimes a vigorous depression centred on the Black Sea envelops the plateau, giving warm southerly winds, till a cold polar air-mass swoops down in its rear as it passes east, and brings bitter weather and deep snow to the bleak open steppes; at such times thousands of sheep may perish. Snow falls on an average on 20 to 30 days a year in the middle of the plateau, 50 to 60 days in the valleys of the east, and it lies most of the year on the highest mountains; it is much deeper as well as more frequent in the east.

Ankara (alt. 2,789 feet) represents the conditions in the central, lower part of the plateau, with its mean temperature only 31° in January and an absolute minimum −13°, a reminder that the winter cold can be severe; summer is hot, the July mean being 73° and the absolute maximum 99°, but the hot, sunny days are followed by pleasantly cool nights. The climate is more extreme towards the east with increasing altitude and more continental position; Sivas, in a valley-bottom, alt. 4,167 feet, has a January mean as low as 22°, and absolute minimum −35°; the summers, however, in these high but enclosed valleys are not much cooler than on the lower plateau, the July mean at Sivas being 67°, absolute maximum 102°, but frost may occur in every month except July and August. Still farther east the winters are much colder and the summers a little cooler (Erzurum, alt. 6,168 feet, January mean 12°, absolute minimum −17°, and readings below zero have been recorded in all the months November to April; July mean 66°, absolute maximum 89°). In summer the plateau is almost cloudless, with no rain save an occasional thunderstorm to temper the aridity of the sun-baked land and lay the dust; nearly all the precipitation is in spring, autumn, and winter, most of it in April and May, and the mean annual total is only 10–15 inches, of the less agricultural value since much of it falls in heavy showers. Summer, and especially late summer, is rainless (Fig. 82); the most arid region, little better than a desert of sand and salt, with an annual mean

less than 8 inches over a roughly circular area 150 miles in diameter, lies round, and south of, the large salt Lake Tuz.

The east of the plateau resembles the rest in its almost cloudless summers, but the winters are more cloudy, with about 6 tenths mean cloud; the mean annual precipitation, much of it snow, is 15–20 inches in the valleys, far more on the ranges.

The Mediterranean Littoral. Continuing south across the Taurus, which has a harsh mountain climate of hot arid summers but cold winters with much snow (lying throughout the year on the higher slopes sheltered from the sun), we return to a normal Mediterranean landscape on the coastal plain. The southward exposure and mountain background make the climate warm even in winter; frost occasionally occurs in the months December to April, but is never severe (absolute minimum at Antalya 24°, at Adana 19°); snow is very rare except on the mountains, which receive enough to be a useful source of irrigation for the plains. The summers are hot, with maxima exceeding 110°, and the coasts of the Bay of Antalya in particular are notorious for heat and malaria. The sea-breeze is very welcome, setting in nearly every day about 0800 and tempering the excessive heat, but its humidity can be as unpleasant as the heat of the air it replaces. Autumn is sultry and oppressive as on most Mediterranean coasts.

The precipitation is considerable, from 25 to 45 inches a year on the coast and probably up to twice as much on the mountains, the amount varying greatly according to the altitude and the orientation of the slopes; winter and spring are the rainy seasons. Heavy downpours and long droughts are frequent, the rainfall being unreliable; in most years July and August have no rain, and June and September very little (Fig. 82). Summer is almost cloudless, but has occasional fog and haze, and even in winter the skies cannot be described as cloudy. With good irrigation facilities, as round Antalya and Adana, Mediterranean agriculture flourishes luxuriantly; cotton is a valuable product of the Seyhan plain (the district of Mersin and Adana). The dust lying inches deep on the ground, and the clouds of white dust whirling over the plain through the hot shimmering air behind moving vehicles on a windy day are a visible sign of the aridity of the Mediterranean summer.

The rich coastal lowland is the more impressive by contrast with the arid steppes of the plateau only a few score of miles distant.

In the south-east Turkey includes the high valleys of the Tigris and the Euphrates, which head back into the lofty highlands of the eastern plateau, and also the north of the plains which spread far south into Syria, the climate of which it shares.

West Anatolia. The west of Anatolia has wider coastal lowlands, which are carried some distance inland by wide valleys, and the plateau itself is considerably lower than farther east; the climate is similar to that of the south coast just described, but the cultivation is more intensive and luxuriant. At Izmir (Smyrna) the mean January temperature is 46° and in most winters the temperature falls to about 25° (absolute minimum 12°); snow is rare. Summer is of the usual Mediterranean type, hot and very sunny, the July mean near the coast being about 80°, with maxima over 100° (absolute maximum at Izmir 111°). The normal winds in summer are fairly strong from NW. (etesian winds), and these, strengthened by the regular sea-breeze in the daytime on the coast, are a great boon in moderating the heat, which is excessive and enervating in the sheltered valleys out of their reach; but in winter floods of cold air sometimes sweep down these valleys from the interior and reach the coast; the most frequent winds in winter are SW. and NE. Precipitation is moderate, the annual mean ranging from 15 inches in the most enclosed valleys to 30 inches on the coast; summer is almost rainless, but with occasional heavy thunderstorms.

Syria, Lebanon, Israel (Palestine)

A true Mediterranean climate, similar to that of the south coast of Anatolia, is found only on the littoral, and not on all of it. Altitude and latitude are effective factors. The land rises eastward, in Lebanon to the Lebanon and Anti-Lebanon Mountains, which reach heights of 10,000 feet, enough to develop a mountain climate; the rise in Palestine is much less, to about 3,000 feet, where high-steppe conditions prevail. A striking topographical and climatic feature is the Rift valley, which runs meridionally as a narrow and very steep-sided trench (here about 10 miles wide) between Lebanon and Anti-

Lebanon (where it is called the Bekaa), and through the highest part of the plateau between Palestine and Jordan, where it contains the Dead Sea, sunk about 1,300 feet below sea-level, and the River Jordan, and is known as the Ghor; thence it continues to the Red Sea and on to the south of Africa. East of Lebanon and the plateau of Palestine Mediterranean climate does not extend; on the plateau beyond about 40 miles from the Mediterranean shore first steppe and then desert proclaim themselves in the rapid decrease of humidity and precipitation and the increasingly continental temperatures.

Coastal Syria and Lebanon have the best Mediterranean climate of the region, with fairly good rainfall, 35 inches a year at Beirut; the rain decreases southward to 24 inches at Haifa, 20 at Jaffa, and only 4 at El Arish (Egypt) on the desert coast which encloses the sea in the south-east. In a west-east direction precipitation first increases with altitude, and here again Syria is favoured in having the highest mountains; the annual means rise to 60 inches in Lebanon and Anti-Lebanon. Israel is much less well supplied, the means on the highest parts of the plateau being only 15 to 20 inches (16 inches at Jerusalem) on the escarpment overlooking the Sea of Galilee and the Ghor. The Rift valley is a narrow but clearly marked rain-shadow, with less than 15 inches in the dry, but not arid, Bekaa, and only about 3 inches in the rocky desert round the Dead Sea (where the mean annual evaporation amounts to 200 inches). East of the elevated edge of the Rift valley the rainfall decreases fairly uniformly over the vast plains to less than 2 inches in the deserts of Syria and Arabia; the climate here is much too dry to be classed as Mediterranean, being of an arid steppe and desert type in respect of temperature as well as rainfall; agriculture is possible only by irrigation. The Mediterranean littoral gets its rain in the winter half-year, beginning in October, increasing to a maximum in January, and ending in April, but it is liable to large variations in amount and season; summer is always very hot, dry and sunny, with little or no rain in the months May to September (April to October in the south). The steppes in the east also get all their precipitation in the winter half-year, most of it in the months November to February; the amounts are small, and very variable from year to year.

The rapid increase in continentality towards the interior is shown by the temperatures at the four stations in the table below. The winters in the steppes and deserts are much colder and drier than near the Mediterranean; cold bleak N. and NE. winds and frost and snow are not rare; snow often lies deep on the higher parts of the plateau (not seldom round Jerusalem), and patches persist throughout the year on the higher Lebanon. Summer is certainly hot, the July mean being over 80° on the coast and rising to nearly 90° on the lower altitudes of the deserts in the east. The hot, dry, sirocco winds that occur in most of the south-east Mediterranean region are frequent in spring. Warm W. winds of a different type sometimes blow at the east foot of the Anti-Lebanon; their warmth is a föhn effect.

		Mean temp.			*Abs. extremes*		*Mean diurnal range*	
	Alt. feet	*Jan.*	*July*	*Ann. range*	*Max.*	*Min.*	*Jan.*	*July*
TURKEY								
Samsun .	26	43[1]	74[2]	31	96	22	..	16[2]
Ankara .	2,789	31	73	42	99	−13	22	33[2]
SYRIA								
Beirut .	121	57	83[2]	26	107	30	12	14
El Kareya (Lebanon) .	3,330	41	72[2]	31	97	21	8	16
Damascus .	2,264	44	82	38	113	21	15	31
Palmyra .	1,329	45	85	40	120	18	19	33
ISRAEL								
Tel Aviv .	105	55	81[2]	26	115	37	15	18
Jerusalem .	2,485	47	75[2]	28	107	26	13	25[2]
ARABIA								
Aden . .	123	79	92	13	109	61	12	11
IRAQ								
Baghdad .	110	48	94	46	121	12	20	33[2]
Basra . .	60	52	97[2]	45	125	19	20	32[2]
Rutba .	2,020	44	87[2]	43	114	10	20	33[2]
IRAN (PERSIA)								
Tehran .	4,002	35	85	50	109	−5	18	28
Jask . .	13	67	91	24	113	42	14	12

[1] February. [2] August.

ARABIA, OMAN, KUWAIT, JORDAN

General conditions. This large and compact block of land extends about 1,400 miles from north-north-west to south-south-east, between the parallels of 33° and 13° N., with a

width of 700 miles in the north, 1,200 miles in the south. Consequently the differences of climate are considerable, and the contrasts are increased by the relief, and by the fact that the north and middle of Arabia are within the range of the Mediterranean depressions in winter, and the south projects in summer into the SW. monsoon of the Indian Ocean. Climatic data are few, and little except general description is possible. Arabia as a whole resembles the Sahara closely, being like it a trade-wind desert, intensely hot in summer (the mean temperature in July exceeds 95° in the hottest parts, and 90° everywhere except on the coast of the Arabian Sea); the overhead sun pours its fierce rays from the cloudless sky, and the glare and the heat are intensified by reflection and radiation from the torrid sand.

In winter the NE. winds bring continental polar air from the interior of Asia and make Arabia cool for its latitude, the mean temperature for January being a little below 60°, rising to over 70° in the south. The NE. winds veer to E. in the Gulf of Aden and ESE. through the Strait of Bab-el-Mandeb; the winds in the Red Sea are described on page 32. On the south-east coast the northerlies are strengthened, sometimes to a gale, in the night and morning by the usual land-breeze reinforced by mountain-winds from the valleys that descend to the coast; they are hazy and may be sand-laden.

In summer NW. winds blow, with little interruption except for local effects, everywhere north of 20° N.; Yemen, Aden, and Hadhramaut are within the SW. monsoon, which is strong, often of gale force, in the Gulf of Aden and all along the south-east coast.

With the large annual range of temperature goes a very large diurnal range; the winter nights are cold, especially in the north, with frequent ground-frosts and occasional snow even on the lowlands, and the summer days are scorchingly hot. Strong winds often raise dust- and sand-storms, a real scourge. The summer heat is such that life would be impossible but for the physiological cooling by evaporation in the dry winds, but this advantage is much less on the coasts.

Precipitation is scanty and very unreliable; probably 5 inches would be a liberal estimate of the annual mean on the

plains. Most of it, north of 20° N., falls in the cold fronts of Mediterranean depressions as short, heavy showers, some with thunder (mostly in spring), hail, and snow, which may be of some intensity. The rain is too scanty and sporadic to provide surface water, but it maintains underground supplies which are tapped by deep-rooted plants, and wells, some of them perennial, give man his necessary supplies. South of 20° N. the SW. monsoon has varying influence; it gives useful rains in the highlands of Yemen.

The coasts.

The littoral on the Red Sea (where it is called the Tihama) and the Arabian Sea is narrow, less than 30 miles wide (and in places much less) except between Hadhramaut and Oman, and very steeply walled in by the plateau. The dazzling bare yellow sands, the brighter by contrast with the ultramarine of the sea, and the many dunes proclaim the aridity; it may be described as a rainless tract but subject to very occasional showers which give most of it an annual mean of less than 2 inches (Jidda 3·1 inches); the heavy dews contribute some scanty additional moisture.

In summer the days are intensely hot (Jidda, August mean 88°, absolute maximum 115°), and the physiological temperature is increased by the direct rays of the overhead sun in a cloudless sky and the radiation from the hot sands; the high, at times very high, humidity makes the climate much more trying for man than in the hotter but drier interior; the nights are damp, sultry, and very enervating. But the fresh breezes in the day are some alleviation, though counteracted by the dust and sand they raise, and the daily sea-breeze is too humid to be altogether welcome. The winters are much cooler, but the thermometer never falls below 60° in the southern Tihama, and even in the north never to freezing-point. The south of the Red Sea and its coasts have the highest mean annual temperature on the globe.

Outside the Strait of Bab-el-Mandeb the summers are cooler; Aden has a mean temperature 92° in June, the warmest month, and the thermometer has never risen above 109 (or fallen below 61°); thus it is appreciably cooler than at Berbera on the Somali coast opposite, where the winds are

off-shore. Mukalla, farther north-east, has no higher record than 100°, and none lower than 67°.

The Western Highlands. These rise very steeply from the coast and Jordan valley and slope more gently eastward. They are hardly less torrid than the lowlands on summer days, when maxima often exceed 100° (Mecca, 1,970 feet, claims an absolute maximum 117°), but much colder in winter, ground-frosts being frequent and the air temperature falling to freezing-point above 2,000 feet, sometimes even in the south. The precipitation is too scanty for agriculture except in the south.

The highest and most important section is Yemen and Aden, which rise in the west above 8,000 feet. Yemen is favoured in its precipitation, with annual means rising to between 20 and 30 inches; the rainiest months are July and August with about 4 inches each, the major rains, from the SW. monsoon, mostly falling from massive clouds in heavy afternoon showers with thunder. Minor rains usually occur in March and April, as in Abyssinia. The western slopes of Yemen have the additional advantage of frequent mists or low clouds which give moisture at night and shade from the sun in the afternoon; they contain the best agricultural land of Arabia, growing good cereals and fruits, and famous coffee. The highest elevations have a harsh climate for the latitude, being often enshrouded in cold, damp cloud and sometimes covered with deep snow in winter. On the more sheltered eastern, lee, slopes of the highlands, short series of observations at Sana, 7,200 feet, show a mean annual precipitation about 15 inches; the summer days are hot, but the nights are cool, especially in winter, under the clear skies, and pools of water may freeze over though the air temperature is well above 32°. The lowest air temperature recorded was 17°; the monthly means ranged from 68° in summer to 59° in winter, which suggests that the climate is among the most pleasant in Arabia.

Central Arabia. The middle of Arabia, including the deserts of Neft and Nejd, at altitudes between 1,000 and 2,000 feet, has a Saharan climate. The summer heat is intense, the daily maximum often exceeding 120° and the minimum at night remaining above 80°; the glare and heat of the blazing sun,

both direct and reflected from the torrid sands, add greatly to the effect of the high air temperature, recalling the littoral of the Red Sea, but the dryness of the air is a great advantage, and evaporation in the brisk wind reduces the physiological temperature so that life is possible though not comfortable. Winter is cool for the latitude and the nights can be unpleasantly cold, with frequent ground-frosts, and in the north, including Jordan, occasional snow (but usually rain) from Mediterranean depressions. Most of the rain falls in short but heavy showers, very variable in amount from year to year; the mean annual totals are well under 10 inches, and probably under 5 inches in most of the interior.

The low littoral along the Persian Gulf has a much more trying climate owing mainly to high humidity and less bracing winters; but the winter temperature can be low, as in Iraq, with a strong northerly wind from Russia; 27° has been recorded even at Kuwait on the coast at the head of the Gulf. For the natives, and much more for Europeans, the summer is trying and can be dangerous owing to the high humidity, particularly when the air is calm or a sluggish sea-breeze drifts in, heavily charged with heat and moisture (the surface water of the Gulf has a mean temperature about 90° in August); wet-bulb readings above 95° have been noted on Bahrain Island. A shamal sometimes brings very different air, hot indeed but dry and dusty, from Iraq. Heavy dews are frequent and are of some value for agriculture in this almost rainless land.

The coastal lowland widens in the south, on the west of Oman, into an extensive desert, equally low and almost waterless except where some oases get underground supplies fed by streams from the mountains.

Oman. Actual records are very few, but it is possible to sketch some main features of the rainfall of the north. The mountains, with large areas over 7,000 feet, have less rain than the highlands of Yemen, and most of it falls in winter, not summer; the annual mean is estimated at 15 to 20 inches. The western slopes, facing the W. winds, have rather more, and parts are even thinly forested and cultivated. The low, narrow, coast on the Gulf of Oman is closely screened under the very steep edge of the highland and has less than 5 inches

(Muscat 4 inches), but dates and other products are obtained by the use of underground water and irrigation; the climate resembles that of the littoral of the Red Sea, being almost as hot and uncomfortable in summer.

Iraq

Iraq includes high steppe and desert in the west (rising to 2,000 feet in what is structurally the plateau of Arabia and Syria), a great tract of lowland, little above sea-level in the flats of the Tigris and Euphrates, which extend to the Persian Gulf where they meet the lowlands of Khuzistan (Persia, p. 256), and mountain-ranges in the north-east rising in small areas to over 6,000 feet, some details of which are given on page 255.

Winter. The bold NW.–SE. feature lines over against Kurdistan and Persia exert a strong control on the winds in Mesopotamia; in winter they deflect the general winds blowing from the high pressures on the north, making them NW. But interruptions result from the passage of troughs of low pressure from the Mediterranean, in front of which the winds are SE., with cloudy skies, some rain, and temperatures above the normal, and if the ground is dry they are liable to raise extensive sand-storms until the rain lays the dust; the winds behind the trough are usually not strong, but they are cold and dry and bring clear bright skies after the frontal squall, with its thunder, rain, or snow, has passed. In the western desert the winds are variable. Round the Persian Gulf the SE. winds in front of depressions are called kaus; they may be followed, when the trough passes, for some hours by a strong SW. 'suhaili' with thick cloud, rain, and sometimes fog, a danger for small craft in exposed harbours.

The mean January temperature is 31° at Diyarbakir, 44° at Mosul, 48° at Baghdad; 12° has been recorded at Diyarbakir and at Mosul, and once for a spell of 9 days the temperature at Mosul remained continuously below freezing-point, an indication that the winters can be severe in the north at the foot of the snow-covered ranges of Kurdistan. The absolute minimum at Baghdad is 12°. Near the Gulf the winters are warmer; the January mean at Basra is 52°, both the days and the nights being warmer than up-country, but even at Basra

the absolute minimum is 19° (which, however, is much below the average winter minimum), and the sides of the Shatt-al-Arab may be frozen. Snow falls throughout Iraq, heavily in the mountains, and its melting on the ranges which feed the Tigris and Euphrates gives those rivers their highest floods in March, April, and May, when the Tigris at Baghdad rises about 17 feet above its mean lowest level which is in late summer; if heavy rains fall on the mountains while the snows are melting rapidly floods are widespread, and the Tigris has been known to rise 12 feet in a day in its lower reaches.

The Mediterranean depressions are the source of all the precipitation, but the total is less than 10 inches, dwindling southward to below 5 inches, and in the middle and west of Mesopotamia to below 3 inches; at the other extreme, the mountains of Kurdistan have over 40 inches. The rains normally begin in November and continue, very intermittently, till April; June to October is rainless. Much of the spring rain falls in thunderstorms, which may be violent in the north-west (and in the adjoining south-east of Turkey), where the plains are already sun-baked but the ranges still cold with their covering of snow. The precipitation is very variable from year to year; Baghdad has had as little as 2·0 and as much as 17·3 inches. Even winter, the rainy season, has little cloud, only about 4 tenths in the lowlands and the western desert.

Summer. In summer the winds are still NW., blowing down the Mesopotamian corridor under the influence of the low pressures of south Asia, and are well known under the name of Shamal. Being free from cyclonic disturbances they are remarkably constant, much more so than the winds of winter; they may be very strong and carry clouds of dust and sand during the day, but they fall almost calm at night. In the western desert the winds are W. and NW. Everywhere the sky is cloudless, the sunshine fierce (Baghdad has a mean of 3,420 hours a year), and the air extremely dry. Such conditions may continue in full strength for several days. At Baghdad the mean temperature in July is 94°, and the maximum reaches 110° on most days in July and August; the absolute maximum is 121°. The heat would be still greater and less bearable but for the strong winds, Iraq being more fortunate in this respect

than north-west Pakistan, where similar temperatures are more enervating in the calmer air. The natives take refuge where possible in underground chambers in the daytime, and pass the nights on the house-tops in the comparatively cool, though light, breeze—but the mean minimum temperature on July nights at Baghdad is 78°. The summers are hotter, and much more uncomfortable, near the Gulf, with its greater humidity and the more sultry nights, especially when the air is calm or a light breeze comes in moist from the hot sea; even Basra—and Basra is 60 miles distant from the Gulf—has a mean of 97° in August, with mean daily maximum 112°, mean daily minimum 80°, and an absolute maximum 125°—truly a heat-stroke climate. In the western desert the mean temperature is somewhat reduced by the altitude, the August mean at Rutba being only 87° (absolute maximum 114°). The diurnal range in summer is fairly large, 30° to 35°, everywhere, but the reduction from the day maxima still leaves the nights very hot. The large annual range is shown by the fact that the rapid Tigris has been known to freeze at Mosul where in summer 120° has been registered.

In the summer months all the scanty steppe vegetation is dried up, and the plains lie deep in fine dust always ready to be swept up by the strong wind. The sky is cloudless, but is white rather than blue owing to the dust-haze and the irregular refraction; visibility is often bad not only on the land but far out over the Persian Gulf. Some dust-storms grow to great heights, over 10,000 feet having been noted by aircraft.

Iran (Persia)

The large differences in relief and in distance from bodies of water are clearly reflected in the climates. Most of the country is plateau, much of it about 3,000 feet above sea-level, but sinking to under 1,500 feet in Seistan, the Lut desert, and Rudbar. The plateau is bordered on the north by the Elburz Mountains, long ranges of which exceed 6,000 feet and rise in places to over 18,000 feet, and on the west and south-west by the Zagros Mountains, a great series of ranges extending for about 1,000 miles over a width of about 250 miles, most of the area being over 6,000 feet, much of it over 10,000 feet, and many summits exceeding 12,000 feet. The plateau and

these bounding mountains form nearly the whole of Persia. In strong contrast are the narrow but important lowlands. Round the south of the Caspian Sea they sink to 60 feet below sea-level; along the Arabian Sea (in Makran) and the Persian Gulf their width below 1,000 feet above the sea is about 25 miles, and they are continued towards the north-west by the alluvial flats of Khuzistan, the basin of the Karun River and its tributaries, an extensive lowland 100 miles long and 100 miles wide, sun-baked and arid in summer.

Winds. In winter the prevailing winds are northerly, but variable owing to the passage of depressions, 2 or 3 a month on the average; calms are frequent. In summer northerlies and westerlies are dominant in the north and west of Persia; in Khuzistan and the Persian Gulf these are the same as the shamal of Iraq, and they often blow strongly for long spells. But the south, including the coasts of the Arabian Sea, being south of the axis of the monsoonal low pressures, has westerlies and southerlies, with, however, prominent land- and sea-breeze components. Local winds of considerable violence are notable in this land of strong and abrupt relief, intense heat and cold. The general winds are much deflected by the mountain-ranges. Katabatic winds descend the slopes and the valleys at night. Ravine winds sweep with great force on summer days through the gorges leading to hot basins (the Safid Rud is a well-known example). The almost constant 'wind of a hundred and twenty days' from NW. and N., often of gale force, hot, parchingly dry, and full of dust and salt, is the scourge of Seistan from June to September. As in arid lands generally all winds tend to raise clouds of dust and sand and dust-devils; blizzards of snow are not infrequent in winter. In summer salt covers much of the surface, which may be marsh in winter. The wind intensifies the aridity against which vegetation has to struggle.

Temperature. The whole country except the littoral has continental extremes. The winters are cold for the latitude, particularly in the north (January mean at Tabriz, Azerbaijan, alt. 4,400 feet, 17°). South of the Elburz Mountains the winters on the plateau are less cold, but the cool, invigorating days

are followed by very cold, clear, and calm nights; the January mean at Tehran, alt. 4,000 feet, is 35°, absolute minimum −5°; at Isfahan, 5,800 feet, 35°, absolute minimum −1°. It gets warmer southward with the decreasing altitude (January mean at Seistan, 2,000 feet, 45°, absolute minimum 12°) to the shores of the Arabian Sea and the Persian Gulf and the plains of Khuzistan (January mean, and absolute minimum, at Chahbar 66°, 41°, Bushire 57°, 32°, Abadan 53°, 24°); but the cold can be extremely trying everywhere inland when the wind is strong and the ground snow-covered. The Caspian lowlands also, with January means about 40°, are cold for their latitude.

The winter cold gives way to great heat in summer, specially on the lower ground. In April the heat is increasing fast, and in high summer the land is parched by a scorching sun shining day after day from a cloudless sky; fortunately on the plateau the low humidity makes the heat easier to bear, and the nights cool down to about 30° below the day maximum, but they are still hot. The northern plateau at 5,000 feet has a July mean about 82° (absolute maximum at Tehran 109°), but many days at the higher altitudes are pleasant and even invigorating; the lower levels are much hotter (July mean at Seistan 90°, absolute maximum 116°). The coasts are very sultry and enervating, the more so physiologically owing to the humid air from the sea and the small diurnal range of temperature; the August mean at Bushire is 91°, at Chahbar 87° (absolute maximum 112°). The flats and the low and enclosed valleys of Khuzistan and Luristan are furnaces of heat and aridity, with monthly means about 95° and day maxima often over 110° (123° has been recorded at Abadan); the diurnal range of about 30° does not usually bring the night minima below 80°. The narrow Caspian littoral has means about 80° in July and August, and the high humidity, the higher on the swampy flats, makes a very unhealthy malarial climate, but agriculturally this is a favoured region thanks to the moist heat and the irrigation facilities in summer, and the moderate winters; its products include rice, cotton, tea, sugar-cane, dates, and oranges. It is a climatic oasis between the bleak and arid plateau of Iran on the south and the Siberian cold at the far end of the Caspian Sea.

Precipitation. Most of Persia is arid or semi-arid, the scanty precipitation averaging about 10 inches a year; the amount falls to less than 10 inches, and even less than 5, in much of the interior and east of the plateau and also on the littorals of the Arabian Sea and the Persian Gulf (for the arid landscape extends south and south-west to the ocean shore) and in the lowlands of Khuzistan; the least favoured tract is Seistan with less than 2 inches. At the other extreme the Zagros and Elburz Mountains have means of over 20 inches (much in the form of snow) and the north-facing slopes of the Elburz and the littoral of the Caspian over 40 inches (Resht 56 inches); the amounts vary much with the topography on the ranges, from about 50 inches on the windward slopes in the far north-west to less than 5 inches in enclosed valleys (which, however, enjoy good irrigation facilities most of the year). The ranges of Khurasan in the north-east, and those behind Makran in the south, have much less rain, but the latter contain fertile valleys. All these ranges show a sharp contrast between their outward- and inward-facing sides, an abrupt change from deeply-dissected slopes with more or less rain and vegetation to arid tracts of bare grey rock and sand and scanty bush (irrigated areas excepted).

As is usual in south-west Asia, the winter half-year is the rainy period; rain is rare in the months May to October in most of Iran, and the land lies dry, yellow, and brown, under the fierce sun. On the plateau spring tends to be the rainiest season; on the coastal lowlands of the south and south-west and the flats of Khuzistan, winter. On the Caspian littoral the rains begin earlier, and autumn has most; even in summer this humid tract gets some rain. In Iran, as in other arid lands of its type, much of the rain falls in short but heavy downpours; the amount and the rainiest months are very variable from year to year, and the land is sometimes stricken by long droughts.

During most of the year the sky is almost cloudless and the sunshine strong and continuous throughout the day. The mean amount of cloud is about 1 tenth in summer (except on the Caspian littoral, where it rises to 4 tenths), and even in winter less than 4 tenths except near the Caspian where it is 7 tenths.

WIND DIRECTIONS IN SOUTH-WEST ASIA, MEAN PERCENTAGE FREQUENCIES

	N.	*NE.*	*E.*	*SE.*	*S.*	*SW.*	*W.*	*NW.*	*Calm*
TURKEY									
Samsun, Jan.	10	4	4	4	11	29	14	13	11
July	18	14	8	3	13	21	4	9	10
Ankara, Jan.	16	46	9	2	6	7	3	1	10
July	8	28	14	5	5	7	9	21	3
Izmir, Jan.	11	19	22	12	12	2	7	2	13
July	12	15	9	1	2	14	34	5	8
Adana, Jan.	54	29	4	3	1	3	2	5	1
July	4	7	6	17	27	31	1	4	4
ISRAEL									
Haifa (mean of 0800 and 1400)									
Jan.	2	4	14	20	19	14	4	3	20
July	3	1	2	3	16	27	17	9	22
ARABIA									
Aden									
Jan., 0900	19	52	19	3	1	0	0	1	5
1500	9	27	27	12	22	2	0	0	1
July, 0900	4	7	2	21	52	8	1	2	3
1500	0	0	0	17	70	11	0	1	1
Kamaran Is.									
Jan., 1200	0	0	0	3	62	15	5	15	0
July, 1200	19	2	0	3	2	2	6	66	0
IRAQ									
Baghdad (1300)									
Jan.	24	6	5	11	5	5	7	29	8
July	10	0	< 1	0	< 1	4	26	56	4
Rutba (1300)									
Jan.	4	7	13	12	5	10	20	17	12
July	4	1	< 1	1	2	13	55	22	2
IRAN									
Tehran (mean of 0730 and 1730)									
Jan.	7	12	3	3	3	11	3	1	57
July	1	2	1	6	6	9	1	1	73
Seistan (0700)									
Jan.	20	3	4	0	2	1	7	17	46
July	17	0	0	0	0	0	0	79	4
Jask									
Jan., 0800	46	18	10	3	0	0	3	14	6
1600	3	1	7	12	13	13	29	18	4
July, 0800	< 1	7	62	15	2	< 1	5	6	2
1600	< 1	0	< 1	39	35	7	10	8	0

Snow is known throughout Iran in the winter, the frequency and amount being naturally greatest on the mountains, the highest parts of which are snow-covered much of the year. It is not infrequent even on the Caspian littoral, and may be heavy, but it never lies long. The plateau is often covered with a few inches, but it does not lie more than a few days; it is most abundant in the north-east, least in the south; on the south and south-west coasts and the lowlands of Khuzistan it is rare. The snow has much economic value in providing irrigation by the mountain streams far into the hot summer, and in blanketing the crops against strong, cold, drying winds; it also forms a natural source of refrigeration for towns near high mountains.

Afghanistan and Baluchistan

These countries resemble Persia in their plateau configuration, but lie far enough east to share in the Indian monsoon, and in some ways they form a transition region between south-west and south-east Asia. In winter they are less cold than Persia, in summer less hot, but the south-west of Afghanistan and north-west of Baluchistan are in Seistan, and have its climate, described above, in equal or greater intensity. Except in the west Afghanistan has more rain (in the winter half-year) than most of Persia; the mountains in the north get heavy snow. The Indian monsoon gives a feeble secondary maximum of precipitation in July.

CHAPTER XXVI

U.S.S.R.

(RUSSIA IN EUROPE AND ASIA. FINLAND. BALTIC STATES)

European Russia is included with Asiatic for description in this chapter since the Ural Mountains do not form a climatic divide. Travelling east through France and Germany from the western seaboard of Europe washed by the warm and stormy waters of the North Atlantic, we experience a gradual transition, which continues right into the heart of Siberia, but at the Vistula the climate has become definitely continental.

That river forms a convenient if arbitrary boundary between the relatively maritime climates of western and central Europe and the essentially continental type of practically all the Russian territory.

Russia is an enormous unbroken land-mass with an area of eight and a half million square miles. Being in middle and high latitudes it has a very extreme climate, and east Siberia contains the 'cold pole' of the earth, where the winters are the coldest known and the range of temperature largest; Canada is the only land with comparable extremes. In the south hemisphere the continents in similar latitudes are narrow, and consequently the winters are mild.

The region contains vast plains not much above sea-level, so that sea-level isotherms give a closer approximation to actual temperatures than in many countries where a considerable correction to sea-level has been applied. The highest elevations are the Caucasus and the mountains of Armenia, the less lofty Urals, the Yaila Mountains, and the mountains of south and east Siberia.

Pressure and Winds

In January (Fig. 41) the dry cold of central Asia extends and intensifies the high pressures of the Arctic region into the highest known on the globe. Lukchun (100 feet below sea-level), near the centre, has a mean pressure (station level) in January 1,043 mb. (30·8 inches), and readings up to about 1,070 mb. (31·6 inches) have been observed (1,076 mb. at Irkutsk is believed to be the highest record on the earth). The high pressures are both intensified and spread widely over the cold north (in contrast to the summer distribution, when the centre of lowest pressure is in the south). Towards the west an extension of the high pressures projects along lat. 50° N., across south Russia and central Europe to the Atlantic, forming the 'barometric backbone' of Europe, a very important wind-divide. North of it, in north and central Russia and Siberia west of the River Obi, are the westerlies of north-west Europe with their varied air-masses and weathers. South of the axis, in the steppes of Ukraine and Trans-Caspia, north-easterlies bring very dry continental polar air with little intermission. In the east of Siberia N. and NW. winds bring similar

but colder air, the winter monsoon of east Asia. In April and October the general pressure-distribution and winds are similar to those of January, but the pressure in the middle of the continent is considerably less and the surrounding gradients are not so steep; the same high-pressure ridge along 50° N. separates south Russia with NE. winds, from central and north Russia and Siberia with westerlies. Indeed, these features persist from August to April, a period of 9 months.

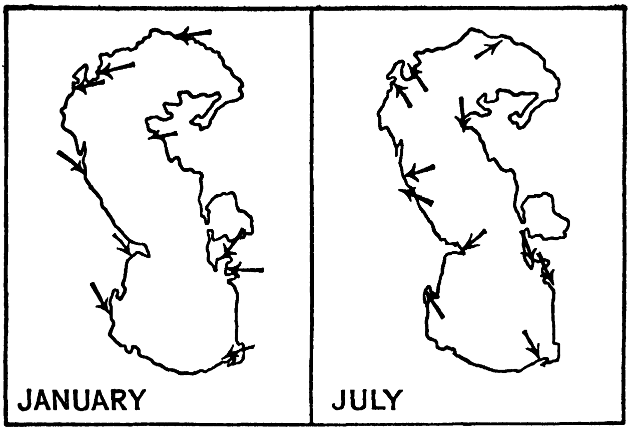


FIG. 83. The prevailing winds round the Caspian Sea.

The outstanding feature of summer (July, Fig. 42), which lasts for only 3 months, is the deep low-pressure system over the south of Asia, centred in Baluchistan. A vast extension towards the north-east covers central and north Asia as a shallow depression with gentle gradients; the mean July pressure at Lukchun is 1,002 mb. (29·6 inches), 41 mb. less than in January. The North Atlantic anticyclone, now much intensified, spreads over central Europe, and can perhaps be recognized as far as Lake Baykal, thus forming a tongue of high pressure as in winter, but directed towards the east. North and central Russia has westerlies and north-westerlies, south Russia north-westerlies in the west and north-easterlies in the east, the latter continuing to the Mediterranean. Trans-Caspia has northerlies, except the vales of the Syr and other rivers in the mountains, where the wind blows upstream, from W. in the Syr, but calms are frequent; north Siberia has

easterlies and east Asia the SE. monsoon. The Caspian Sea shows a seasonal reversal of winds, which blow in winter from the dry, cold, land to the relatively warm sea, and in summer from the cool sea to the hot land (Fig. 83).

Means illustrating the preceding description are:

WIND DIRECTIONS, MEAN PERCENTAGE FREQUENCIES
(observations at 0700, 1300, and 2100)

		N.	*NE.*	*E.*	*SE.*	*S.*	*SW.*	*W.*	*NW.*	*Calm*
Archangel,	Jan.	4	3	13	17	21	15	11	7	9
	July	13	12	10	10	9	7	13	13	14
Leningrad,	Jan.	4	5	6	19	16	14	15	15	5
	July	10	13	9	11	10	11	15	20	2
Moscow,	Jan.	5	2	4	11	19	13	27	9	10
	July	9	6	7	10	12	10	23	11	13
Kazan,	Jan.	9	3	2	12	27	12	12	6	18
	July	14	8	5	6	12	11	15	10	20
Turt-Kul (Petro-Alexandrowsk),	Jan.	25	15	11	9	4	4	7	6	18
	July	33	8	2	2	1	2	12	20	21
Omsk,	Jan.	4	4	7	8	16	22	16	6	18
	July	14	10	7	7	8	10	13	14	18
Irkutsk,	Jan.	10	12	12	31	10	1	3	17	3
	July	6	2	8	28	12	5	15	22	2
Bulun,	Jan.	3	2	1	3	13	25	13	1	38
	July	19	27	8	3	8	13	8	7	7
Vladivostok,	Jan.	31	4	0	1	0	1	1	36	26
	July	4	1	7	53	5	4	2	4	19

TEMPERATURE (Fig. 40)

In winter the warm Atlantic Drift is a greater source of heat for Russia than direct insolation, and the prevailing westerlies of the north and middle of the country carry the oceanic influence far inland. In the south, on the other hand, the prevailing NE. winds are cold from their origin in the heart of the continent. Consequently the isotherms have a general NW.–SE. trend in European Russia and west and central Siberia. With increasing distance towards the north-east it becomes rapidly colder, the temperature decreasing with remarkable uniformity into the north-east of Siberia, where at Verkhoyansk the winters are among the coldest known anywhere, as cold as on the polar ice-caps. The heat of the North Atlantic is more than 3,000 miles distant beyond the frozen continent; the Pacific Ocean

has not much effect the monsoon being offshore, and, moreover, ranges of hills intervene; the ice-covered Arctic cannot ameliorate the harsh conditions to any great extent. The warm Indian Ocean lies far beyond the impassable barrier of the lofty ranges and wide deserts of the middle of Asia. Of direct insolation there is none at the winter solstice, for Verkhoyansk is within the polar circle. In the long winter nights radiation goes on vigorously from the snow-covered ground through the clear, calm, dry atmosphere and the cold air stagnates in the valley-bottoms. The mean temperature in January at Verkhoyansk is $-58°$, the mean minimum of the month $-83°$, and $-94°$ was once recorded, this being the lowest reading ever taken on the surface of the earth. The highest temperature ever recorded in January was $-13°$. The winter cold is less intense towards the north; Sagastyr (delta of the Lena on the Arctic Ocean) is about 25° warmer in January. This results not so much from the influence of the ocean, which is ice-covered hundreds of miles from the shore, as from the stronger winds on the flat, treeless tundra and the absence of strong topographical inversion of temperature. The fact that the 'cold pole' is so far east in Siberia is an indication of the relative importance of the Atlantic and Pacific Oceans in determining the winter climate of Eurasia. The prevailing westerlies, unimpeded by any high mountain-barrier, bring heat for hundreds of miles inland from the Atlantic, and the vapour they contain is effective to the same end by checking radiation. The theoretical probability that the low winter readings of eastern Siberia are due to drainage of cold air into the valley-bottoms, in which most regular meteorological observations are made, and that an inversion of temperature is normal in winter, is strengthened by the records available from elevated stations, which are shown to be considerably warmer. The extraordinarily intense cold is found only in 'frost hollows', of which Verkhoyansk, in the valley-bottom of the River Yana, is one example. It is possible that other similar hollows are even colder, such as Oymyakon, according to observations in recent years; this village is about 300 miles south-east of Verkhoyansk, 3,300 feet above the sea in the valley of the River Indigirka, which is incised in a plateau with mountain ranges rising to 6,000 feet round about. Outside these inversion lakes

the air is much less cold; Semenovski Mine, 250 miles south of Verkhoyansk, in a more continental position but at an altitude of about 3,300 feet on the south-facing slopes of the Verkhoyansk Mountains, has a January mean as high as −21°. But the uplands contain hollows which collect cold air of even lower temperature than the neighbouring lowland valleys. The isotherms drawn on our maps represent the conditions of the valley-bottoms.

Almost the whole of Russia has a January mean below freezing-point. The isotherm of 32° F. crosses the Crimea and the Caspian Sea, and follows roughly the line of the Trans-Caspian Railway across Turkmen, so that only the south Crimea, the lower land of Trans-Caucasia, the south half of the Caspian, and the extreme south of Turkmen have means above freezing-point. And even south of the 32° isotherm a considerable area including Armenia forms an 'island' of cold with a mean below 32°; at Kars, 5,725 feet above the sea, the January mean is 9°. In Trans-Caspia much of the land south of the 32° isotherm is mountainous and has actual temperatures much lower than the isotherms show. To appreciate the significance of the January isotherms for the life of the people it must be remembered that almost all the vast area north and east of the 32° line is snow-covered for some weeks at least every winter, the sledge is the usual conveyance, and the rivers are frozen. The 14° isotherm crosses European Russia obliquely from the north of the Gulf of Bothnia, through Moscow to near Astrakhan. The north-east shores of the Caspian Sea are on the cold side of it, and hence, although the latitude is 47° N., the winters are colder than at Leningrad in 60° N. Almost all Siberia has a January mean below 0° with the exception of the south of the Pacific coast, but even Vladivostok has only 6°.

The warming influence of seas and lakes on their neighbourhood is very prominent in winter. Mariehamn, on the Åland Islands in the Baltic, has a January mean 27°, but Leningrad, 350 miles east at the head of the Gulf of Finland, which, however, is frozen over, only 18°. The White Sea and the Kola peninsula form another striking example; northward along the meridian of 35° E. the temperature actually rises over the White Sea, to fall over Kola and rise again on the

Murman coast. It is worthy of notice that the coldest part of the north-west of Russia is well to the west under the lee of the Scandinavian highlands—an exception to the usual increase of temperature towards the ocean, and a result of the barrier opposed by the highlands to the warm, moist winds.

Proximity to the sea and the shelter of the Yaila Mountains combine to give the south of the Crimea, the Russian Riviera, its mild winters. At Yalta the mean January temperature is 39°, and the lowest reading on record 9°; at Dnepropetrovsk, 280 miles north, fully exposed to the cold NE. winds that sweep over the steppes, the corresponding figures are 19° and −31°. Even Yalta is considerably colder than the north coasts of the Mediterranean Sea, which, however, are in slightly lower latitudes. The coast of the Black Sea at the foot of the Caucasus is another climatic oasis, thanks to the mountain-shelter, a shelter which is felt even on the south coast of the Black Sea. When, however, a deep depression lies over the east of the sea, the lower western end of the Caucasus is unable to keep back the NE. wind, which blusters down as the dreaded bora, an exceedingly strong, cold, dry wind from the steppes, especially prominent in the neighbourhood of Novorossiysk, where ships are sometimes coated with frozen spray.

The isotherms curve northward over the south of the Caspian Sea; but the north of that lake is frozen, and has little or no modifying influence. The Arctic Ocean warms the north of Siberia somewhat, but its frozen surface is not so effective as the open Pacific, on the shores of which the isotherms are closely crowded. The most striking effect is shown by Lake Baykal in December (Fig. 84), when the water is not yet frozen over; the shores of the lake are liable to much fog at this time. In the second half of the winter the lake is completely ice-covered and provides less heat. The shallow Aral Sea freezes over rapidly in the beginning of winter, and thenceforward does not warm its neighbourhood appreciably.

To consider next the lowest readings that have been recorded, the warmest part of Russia is the south-west, the coasts of the Black Sea and the south half of the Caspian, but even here few are the stations where the thermometer has not been known to fall below zero (Odessa −19°). Uzbek and Turkmen have lower records, −15° at Merv, −24° at Nukus

on the delta of the Amu Daria. The whole of the north-eastern half of European Russia, including the coast of the Arctic, and all Siberia have experienced temperatures below $-40°$,

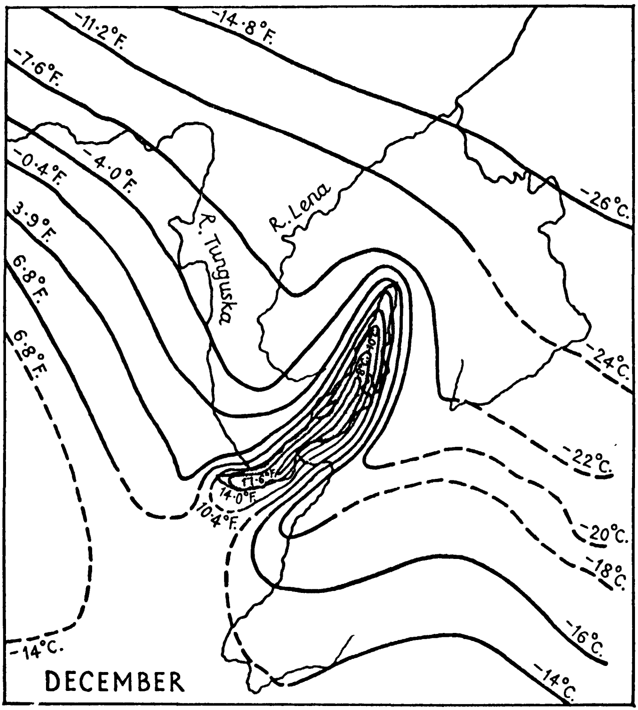


FIG. 84. Mean isotherms, Lake Baykal, December.

all central Siberia below $-60°$, and Verkhoyansk has recorded $-94°$.

The Siberian winter is by no means so unpleasant as these low temperatures might suggest. The air in the interior of the continent is bracing and often calm, so that furs give adequate protection. Vegetation hibernates, to flourish luxuriantly again in the summer warmth.

The inhabitants of the south of east Siberia have no cause to envy the winters of central Europe with their leaden skies, strong damp winds and sudden changes of temperature, which are felt the more because they oscillate about freezing-point. Except on the coasts the sky is beautifully clear, especially between September

and April, and of a deep violet-blue which recalls Italy and north India. The air is transparent and calm, and the bright sunshine is so warm that the snow on the roofs melts though the air temperature is below 0° (WOEIKOF).

It is only the wild buran, the purga of the tundras, that brings danger to man and beast. During these storms the wind sweeps with extraordinary violence over the open plains. The air is thick with snow, descending from the sky and swept up from the ground so that it is impossible to see. Though the temperature is not specially low the cold is felt keenly, and the man who is overtaken runs a serious risk of losing his way and being frozen to death. The buran is known and dreaded in south Russia and throughout Siberia, and except in the forests often closes the passes of the Stanovoy Mountains for weeks together in winter.

Zenzinov describes a blizzard in north-east Siberia:

We ran into a frightful purga on 31 December, while passing through one of the most deserted sections of our route. It started soon after midday, in the form of a slight wind. Around us was the lifeless tundra, under an even blanket of snow. About one o'clock twilight began to descend. Everything was shut off from sight, as if a grey and muddy curtain had been drawn about us. The sky fused with the snow. It seemed as if our reindeer were suspended in the air, their legs moving but without making any headway. The snow was so dense that I could not even see the antlers of the deer drawing my own sled. I would only see their regularly moving rumps. The wind grew stronger. It turned into a hurricane. Currents of snow sped by me, skimming the ground, striking the sled with a dry rustle. Many times I thought we had hopelessly lost our way. . . . The snowstorm would hit me directly in the face, then from the right, from the left, and in the back. . . . What if we had really lost our way? In this open tundra the snow would drift over us and bury us for good.

The air is usually described as very dry. We may be inclined to challenge this statement on finding that the mean relative humidity in January is over 80 per cent. nearly everywhere, and over 85 per cent. in European Russia, figures almost identical with those for England, where the air is notably humid. But it must be remembered that in Russia the air is very cold, and, though the relative humidity is high, the

absolute humidity is very low. On contact with the human body the air is quickly warmed, and becomes much drier than the air in England raised to the same temperature. Physiologically, therefore, the Siberian winter air is 'dry'. A few figures will make this point clearer. In the south of England the mean relative humidity in January is about 87 per cent.

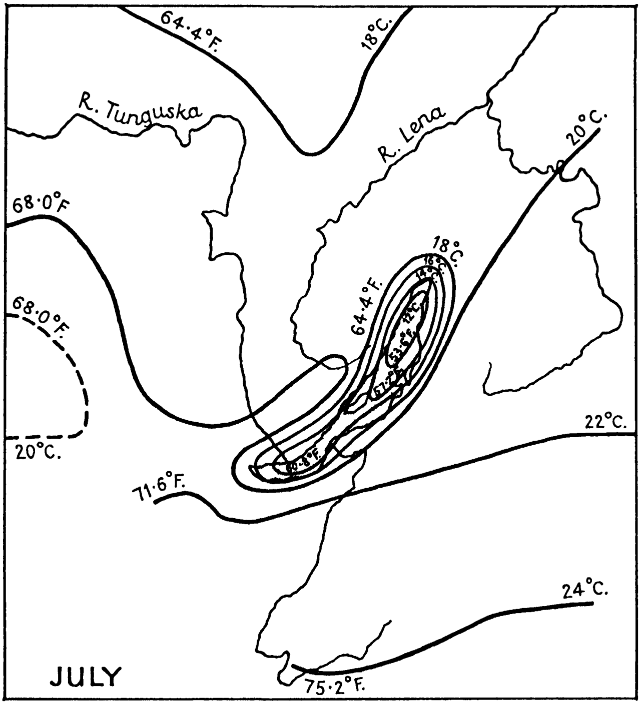


FIG. 85. Mean isotherms, Lake Baykal, July.

and the mean air temperature 40°; when this air is heated to 60° (a figure chosen as an approximation to the temperature to which air is heated near the body) the relative humidity becomes 42 per cent. At Tobolsk the mean relative humidity in January is about the same as in England, 88 per cent., and the mean temperature −3°, so that if the air is heated to 60° the relative humidity falls to 7 per cent., a sixth of the value in England.

In summer the land is warmer than the sea. The July isotherms follow the parallels of latitude more closely than those

of January, except on the Baltic and Pacific coasts, their general trend being WSW. to ENE. The 50° line, the approximate boundary of the tundra, cuts off the northern peninsulas, and the 70° line crosses central Russia and south Siberia. The hottest areas are the deserts of the south, the south of Trans-Caspia having a mean over 86°. The rigours of the continental winter give place in the south half of Russia within a couple of months to the heat of a Mediterranean summer. The effect of bodies of water is considerable though much less than in winter; at Mariehamn (Åland Islands) the July mean is 59°, the absolute maximum 85°, and at Leningrad the corresponding figures are 64° and 97°. The interior of the Kola Peninsula is somewhat warmer than the coasts. The isotherms show characteristic southward loops over the Caspian Sea. The Arctic and Pacific coasts are cooler than the interior of Siberia, and indeed the climate of the Pacific coastal strip is unpleasant in summer owing to the chilly damp and foggy SE. winds that blow almost constantly from the sea. Lake Baykal cools its neighbourhood appreciably (Fig. 85).

The highest temperatures recorded in the tundra of the extreme north of Russia and along the Baltic coasts are about 86°. It is a striking illustration of the regulating effect of bodies of water that no higher maxima occur in lat. 55° on the Baltic than in lat. 71° in the Arctic deltas of north-east Siberia. The summer maxima, like the summer means, are highest, over 105°, in Turkmen.

The temperature is far more uniform in July than in January:

	January		*July*	
	Mean temp.	*Abs. min.*	*Mean temp.*	*Abs. max.*
Batumi	43	18	74[1]	95
Tashkent	30	−15	80	109
Leningrad	18	−35	63	97
Moscow	14	−44	66	99
Tomsk	−3	−60	64	95
Yakutsk	−46	−84	66	102
Verkhoyansk	−58	−94	59	93
Difference between extreme values .	101	112	21	16

[1] August.

A most significant element, especially in continental countries in middle and high latitudes, is the range of temperature from summer to winter. In Russia it is so large that a

statement of the mean annual temperature, which includes such widely different extremes, is without much practical value. The lines of equal range of temperature (Fig. 86) are strongly reminiscent of the winter isotherms whose influence evidently outweighs that of the summer. The smallest range is in the west, but even on the Baltic coast it is 36°. Similarly on the coasts of the Arctic and Pacific Oceans, the Black Sea,

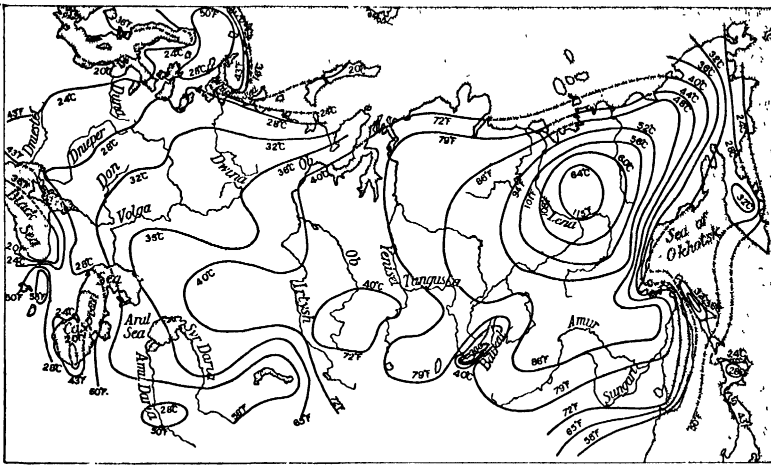


Fig. 86. Mean range of temperature.

the Caspian, and Lake Baykal, it is notably less than inland. In the interior the range increases from 36° in the west to 65° in the east of European Russia, and almost all Siberia except the Pacific littoral has the enormous range of over 70°. Round Verkhoyansk, in almost the same position as the winter cold pole, is the largest range on the earth, over 110°. The following table shows more clearly how rapidly the range increases from west to east (see also Fig. 87):

Mean Temperature

	January	*July*	*Range*
Riga	24	64	40
Moscow . . .	14	66	52
Kazan . . .	7	68	61
Tobolsk . . .	−3	64	67
Tomsk . . .	−3	64	67
Yakutsk . . .	−46	66	112

Where the range is so large it is evident that the change from month to month must be very rapid, especially in spring

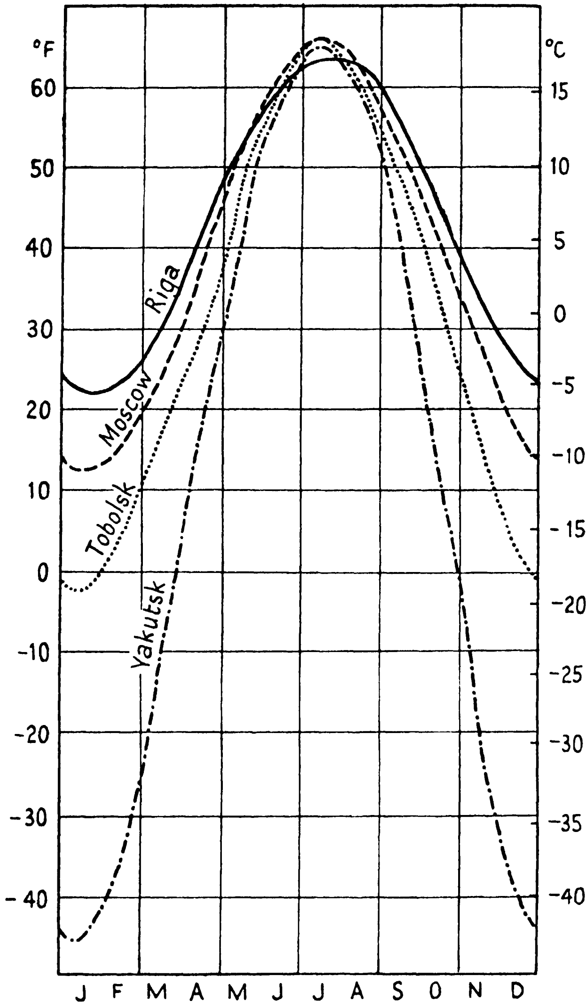


FIG. 87. Mean temperature.

and autumn. At Verkhoyansk the mean drops 40° from October to November. This is an extreme case, but even Moscow, in the west, has a change of 16° from April to May.

Almost all the world over outside the tropics, autumn is warmer than spring, especially in maritime climates, although the sun is higher in spring than in autumn. The air temperature lags behind the sun for such causes as snow to be melted,

wet ground to be dried, or, most effective of all, the presence of a body of water with its conservative thermal tendency. The ordinary rule holds good in most of the Russian lands, notably on the coasts of the Baltic and Black Seas, but Turkmen and the steppes of Kazakh are anomalous in having spring warmer than autumn (Tashkent and Turt-Kul in table below). Here air temperature follows insolation closely with little lag. Contributing factors are the absence of large bodies of water, and also of trees, for the winter winds are strong and the snow, never very deep, is swept away, so that the spring rise in temperature with the increasing power of the sun is not delayed by the diversion of energy to melt snow or dry the ground. The same peculiarity is found in the interior of east Siberia, but on the coast of the Pacific the usual excess in autumn is strongly marked:

	Mean Temperature	
	April	*October*
Tashkent	58	54
Turt-Kul (Petro-Alexandrowsk)	58	52
Verkhoyansk (interior)	8	6
Okhotsk (coast)	21	28

It is interesting to compare the temperatures of the deserts of Trans-Caspia and of Sin-Kiang beyond the Pamirs, for the most part at a considerably higher altitude:

	Altitude feet	Mean Temperature		
		Jan.	*July*	*Range*
Trans-Caspia				
Turt-Kul (Petro-Alexandrowsk)	295	23	82	59
Samarkand	2,362	32	77	45
Sin-Kiang				
Lukchun	−100 (approx.)	13	91	78
Kashgar	4,296	23	80	57

Both deserts are of the same general type, with cold winters and hot summers, but Sin-Kiang has colder winters, somewhat warmer summers, and larger range of temperature.

Freezing of rivers and coasts. In winter even large rivers are frozen over in nearly all Russia; the duration of the ice (Fig. 88) is an important element biologically and economically. In

the south-west the Dniester and the middle Vistula are ice-bound for over 70 days in an average year. In the middle of European Russia, including the middle and upper Volga, the period is 150 days, and in the north over 200 days. The 120-day and the 160-day lines mark off three nearly equal parts: south, where the rivers are frozen for less than 4 months, central for 4 to $5\frac{1}{2}$, and north for $5\frac{1}{2}$ to 7 months. In the whole of Siberia the rivers are frozen for at least 5 months,

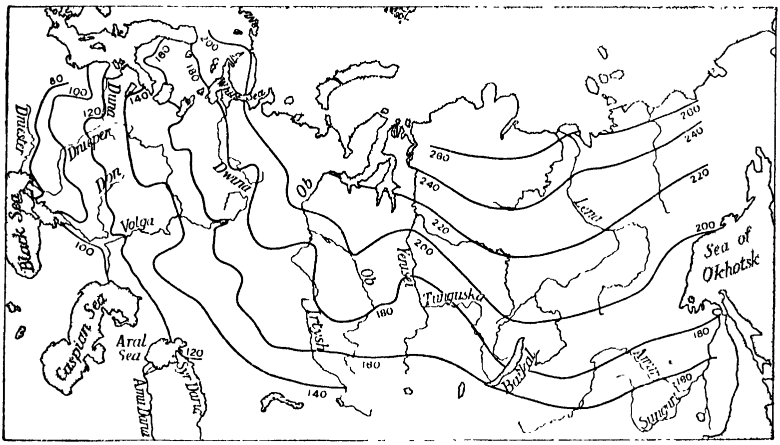


FIG. 88. Mean annual number of days rivers are frozen.

and in the extreme north open water is to be seen only for 3 months in the year; many rivers and lakes are frozen to the bottom. The air temperature is below freezing-point for 10 to 20 days longer than the period during which the rivers are frozen, so that a general idea of the duration of the frost may be obtained from Fig. 88.

Russia labours under another serious disadvantage in the freezing-up of her ports, even on the Black Sea, parts of the north-west shores of which, exposed to the cold NE. winds from the steppes, are ice-bound during January and February; the port of Odessa is closed on the average from 24 January till 19 February. The Sea of Azov is frozen right across in mid-winter, and is bordered with ice for 80 days in the west and over 100 days in the north-east. The north half of the Caspian is frozen near the coasts every winter, the ice remaining about 100 days in the north. On the Baltic, Liepaja on the open coast

is occasionally free of ice throughout the winter, but the east of the Gulf of Riga is blocked for 130 days, and the shores of the Gulf of Finland for 140 to 150 days, from early November to the beginning of April (the east of this gulf is frozen over completely for about 3 months). In the Gulf of Bothnia the conditions are still worse, for the north freezes up in the middle of October and is not open again till the middle of May, after

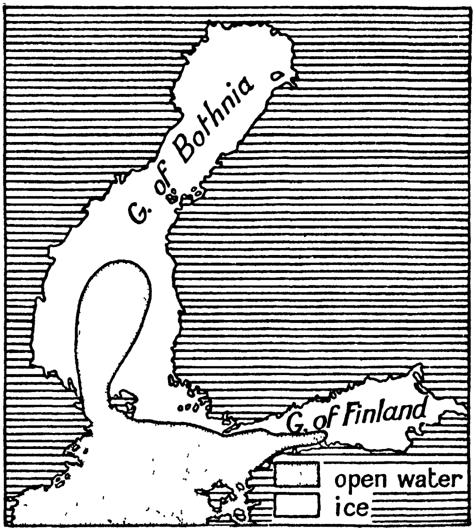


FIG. 89. Extent of ice in Gulf of Bothnia, 1 March 1905.

210 days; it is sometimes frozen almost across even as far south as the Åland Islands (Fig. 89).

With regard to the north coast of European Russia it is an interesting fact that the farthest north is the least obstructed by ice; for the Murman coast, between Varanger Fiord and the White Sea, derives such benefit from the Atlantic Drift that in some years it has no fixed ice, and only in very exceptional years has it been ice-bound for as much as 5 months. Access to winter ports on these Arctic shores is of great value in time of war as of peace. The coast east of the White Sea, being farther from the Atlantic warmth, has ice for 8 months in an average year. Similarly in the White Sea, the north, thanks to the warm drift, is not frozen longer than Onega Bay, the most remote arm of this sea 200 miles south, the average duration

of the ice being 200 days. The Gulf of Archangel freezes in the end of October, to remain blocked for 140 days, and the port of Archangel is closed for 190 days.

The north coast of Siberia is ice-bound most of the year, for the permanent ice of the Arctic Ocean almost reaches Novaya Zemlya and the coast of the Taymyr Peninsula, and it surrounds the north islands of the New Siberian group. Vladivostok harbour is frozen from the middle of December till the beginning of April. Nikolayevsk at the mouth of the Amur is closed from the middle of October till the end of May.

The River Amur at Blagoveshchensk is frozen from the end of November to the middle of May; the ice in midwinter exceeds 5 feet in thickness.

Lake Baykal begins to freeze in November, but is not completely frozen over till the end of December. It remains frozen about 4 months, till the end of April, and the ice is sometimes 9 feet thick. Sledges are used for crossing the lake during the winter months.

Precipitation

As might be expected in a country of monotonous relief, the precipitation tends to be uniform. In a wide belt through central Russia and south Siberia it is moderate, about 20 inches in European Russia, and over 20 inches in the extreme east where it is brought by the SE. monsoon; the middle of this belt, from the Urals to the Amur, has about 15 inches. North of the central belt there is considerably less, under 8 inches in the tundra owing to the cold. South of it also precipitation is deficient under the dry NE. winds throughout the year. The driest region includes the deserts of Kara Kum and Kysyl Kum with less than 4 inches, and between them and the central belt are the steppes with 8 to 15 inches. Even the coast of the Black Sea between the mouth of the Dniester and the Crimea with prevailing NE. winds from the steppes has only about 12 inches, evenly distributed over the year. But the coast farther east at the foot of the Caucasus has copious rains, rising to over 60 inches, and is the rainiest part of Russia; most of the precipitation is of the Mediterranean type, associated with the fronts of winter depressions on the Black Sea.

In most of Russia summer is the rainiest season (Figs. 46 and 90), for in winter the out-blowing winds from the continental high pressures hinder the ingress of vapour. But in summer vapour comes in from both west and east; the winds from the Arctic, however, are cold and their vapour-capacity is increased over the land, so that but little rain is derived from them. The rainfall maximum is in late summer, July and August (Fig. 91, Barnaul), when the inflow of moist air is strongest, and thunderstorms are most frequent, for much of the rain falls

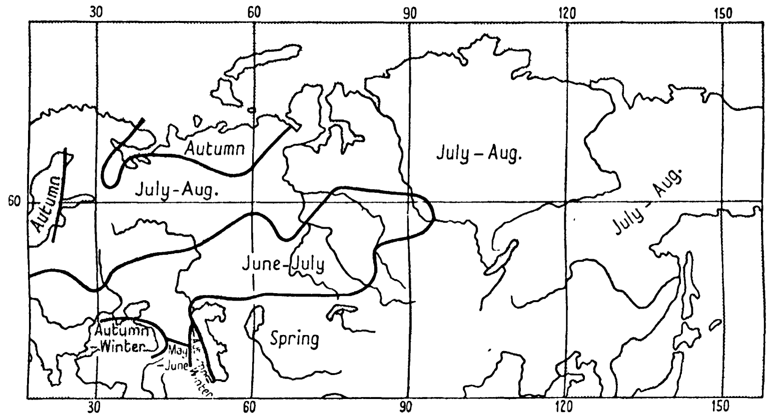


FIG. 90. Periods of the year with most precipitation.

in thunderstorms on summer afternoons; Moscow and Semipalatinsk each have 15 days with thunder in the year, of which Moscow has 11, Semipalatinsk 14, in summer. The rainfall of east Siberia is brought by the SE. monsoon, almost all in summer, most in late summer; Vladivostok has 21 inches, and the amount decreases towards the north. At Okhotsk much of it is drizzle and mist, and the annual total is only 11 inches. The extreme west and north of European Russia get most rain in autumn from the depressions of the westerlies, which are then very active and not yet kept at bay by the high pressures on the continent in winter.

A small region has a winter maximum; it includes only the south coast of the Crimea (Fig. 91, Yalta) and the east of the Black Sea already mentioned as having the heaviest rainfall in Russia. These small areas are the representatives in Russia of the 'Mediterranean' climate, with most of the precipitation

in autumn and winter, but no season can be called dry. On the coasts (except the north) of the Caspian also, and beyond the Caspian to Lake Balkhash, the maximum is in the winter half-year, but the amount is so small and the winters are so cold that the region cannot be classed with the Mediterranean shores. The sharp contrast in temperature between the north and south of the Crimea holds equally in respect of rainfall; south of the Yaila Mountains it exceeds 20 inches a year, most of it in winter, but the steppes on the north have only 12 inches, with the maximum in early summer; snow lies for

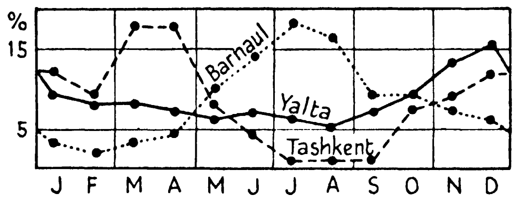


FIG. 91. Mean monthly precipitation, percentage of yearly total.

about 30 days round Nikolayev and 60 days north of the Sea of Azov.

Trans-Caspia has most of its scanty precipitation in March and April. Most of the months December to May exceed a twelfth of the yearly total, and the summer months, July to September, are dry (Tashkent, Fig. 91). The steppes on the north of the desert also have spring rain, with the maximum in May and June when thunderstorms give copious downpours, the rain being so heavy while it lasts that only a small part of it sinks into the ground to become available for plant-life; most runs off at once and is wasted. These heavy showers are due in part to the rapid heating of the dry ground by the sun while the air a few thousand feet above is still cold, conditions favourable to convectional overturnings and thunderstorms. Later in the summer the heat has increased but is more evenly distributed, and in the steadier current large temperature differences are less frequent.

Snow. Though the maximum precipitation is in summer nearly everywhere, winter gets some, practically all in the form of snow from mid-November to March inclusive in almost the whole of European Russia. But on the north shores of the

Black Sea snow is frequent only in the months December to March, and only in January and February is it more frequent than rain; the 'Mediterranean' coast of the Crimea, sheltered by the Yaila Mountains, has little, on only 3 days even in February, the month with most; in the east, round Batumi, snow is much less frequent than rain, but falls on about 4 days in each of the months December to March. Data of the relative frequency of snow and rain at representative stations are:

	Months with snow on more than half the days with precipitation	*Months with no appreciable snow*
Archangel	Oct.–Apr.	June–Sept.
Riga	Nov.–Mar.	May–Oct.
Moscow	Nov.–Apr.	,,
Kazan	Nov.–Mar.	May–Sept.
Odessa	Jan.–Feb.	Apr.–Oct.
Yalta	none	Apr.–Nov.
Baku	,,	,,
Astrakhan	Dec.–Mar.	Apr.–Oct.
Tashkent	Jan.–Feb.	,,
Tomsk	Nov.–Mar.	June–Aug.
Irkutsk	Oct.–Apr.	,,
Yakutsk	,,	,,
Vladivostok	Nov.–Mar.	May–Oct.

The tundra coasts have all their precipitation in the form of snow in the period mid-September to the end of May. The snowfall is heaviest in the taiga, where snow 3 feet deep is not uncommon, and drifts much deeper, for even in winter, despite the high atmospheric pressure, depressions make their way far into the continent. The snow lies deepest in the forest, largely on account of the shelter of the trees. But Siberia has no permanent snow-fields in spite of the intense winter cold, for the not very abundant snow disappears in the long summer days; in spring it melts slowly and the water saturates the ground, conditions favourable for trees. The snow-cover is beneficial in another way, illustrated by the following observations. In January 1893 a layer of loose dry snow 20 inches deep covered the ground at Leningrad, and the temperature on the surface of the snow was −39°, but on the ground under the snow 27°. On a neighbouring piece of ground without snow the temperature was −31° (records quoted by

Woeikof). It is evident that the snow, being a poor conductor of heat, acts as a valuable blanket, protecting the ground from excessive cold. In most of north Siberia the soil at a certain depth is permanently frozen, and the thickness of the snow-cover is a factor in determining whether or not this 'permafrost' occurs. East of Lake Baykal it is found with a mean annual air temperature 25°, there being little snow; but not at Turukhansk (lat. 66° N. on the River Yenisei), though the mean air temperature is 17°, one reason being that the surface is well protected by snow throughout the winter. The steppes south of the taiga have much less snow, and what does fall tends to be swept away by the strong NE. winds, so that even at Krasnoyarsk it is often not deep enough for sledges. We have here an instructive instance of the interaction of climate and vegetation. The trees of the taiga provide shelter, and snow lies deep for a long period, keeping the ground warm and providing moisture when it melts in spring. But the steppes are treeless and windy, snow does not lie, the ground temperature is very low, and there is no water in spring to saturate the earth and enable trees to grow; grasses alone flourish. The animals of the tundra, and also many from the steppes, take refuge in winter in the intermediate forest belt, where they find shelter from the cold winds of the open country as well as a certain amount of food.

When the snow melts the rivers rise in high flood. In May the Volga swells to 25 feet above mean level at Kuybyshev (Samara), and to 7 feet above at Astrakhan where the floods have a breadth of 25 miles. The rivers that flow north are flooded in their upper courses before the ice melts farther north, so that their lower basins are often inundated and contain widespread tracts of marsh. The floods of the Amur occur in summer, being due to the heavy summer rains, not in spring, for the basin has not very much snow; they are very extensive and often do great damage.

The vales that open to the deserts of Trans-Caspia from the south and east owe their fertility to irrigation from the streams fed by the melting of the snow which has collected on the mountains in the winter. Such is the Syr Daria which waters the luxuriant gardens of Ferghana all summer. The

streams that descend from Khurasan and Afghanistan flood in spring, but almost dry up in summer since they have less snow round their sources.

Cloud

Cloud and precipitation do not necessarily have the same annual period. Nearly all European Russia has more precipitation in summer than in winter, but winter is the cloudiest season with 7 to 8 tenths of the sky covered, as much as on the cloudy western seaboard of Europe; most of its cloud is of the stratiform, inversion, type. In west Siberia also winter is cloudiest with about 7, but east Siberia gets most cloud as well as most rain in summer from the SE. monsoon. The vast region is cloudy despite its continentality. The clearest skies are in the steppes, and especially in the deserts which are almost cloudless in summer; Bukhara has only 1 tenth.

Means for representative stations are:

Cloud Amount in Tenths of the Sky Covered, Means of Observations at 0700, 1300, 2100

	Jan.	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*
Moscow . .	8	8	7	6	6	6	6	6	7	7	9	9	7
Sevastopol .	7	7	7	5	5	4	3	3	4	5	6	7	5
Turt-Kul (Petro-Alexandrowsk)	5	5	5	4	3	2	1	1	1	2	4	6	3
Tomsk . .	7	6	6	6	7	7	6	7	7	8	8	7	7
Irkutsk . .	4	4	4	5	6	5	6	5	5	5	6	7	5
Yakutsk .	5	5	4	5	6	6	6	6	6	7	6	6	6
Nikolayevsk .	4	5	5	6	7	6	7	7	6	6	6	5	6

Major Climatic Regions (Fig. 92)

1. The tundra is characterized not so much by its cold winters—those of the north-east interior of Siberia are colder—as by its cool summers. The mean July temperature is below about 50° and the 50° isotherm may be used as the approximate boundary. The ground is frozen hard most of the year, at a few feet below the surface permanently. The surface thaws for a month or two in summer (when the days are 24 hours long or little less), but is then waterlogged, except on south-facing slopes. The precipitation is small, but the air is damp and raw.

2. This is an extensive region which has its rainfall maximum in late summer, but no season is without precipitation;

it has much snow in winter. Winter is very cold, the thermometer rarely rising above freezing-point, but summer is warm, the July mean exceeding 50°, and 65° in the south.

Subdivisions, A, B, C, D, E, according to temperature are necessary, based firstly on the winter cold, which becomes more intense eastward into Siberia, and secondly on the summer heat, which increases from north to south. But the

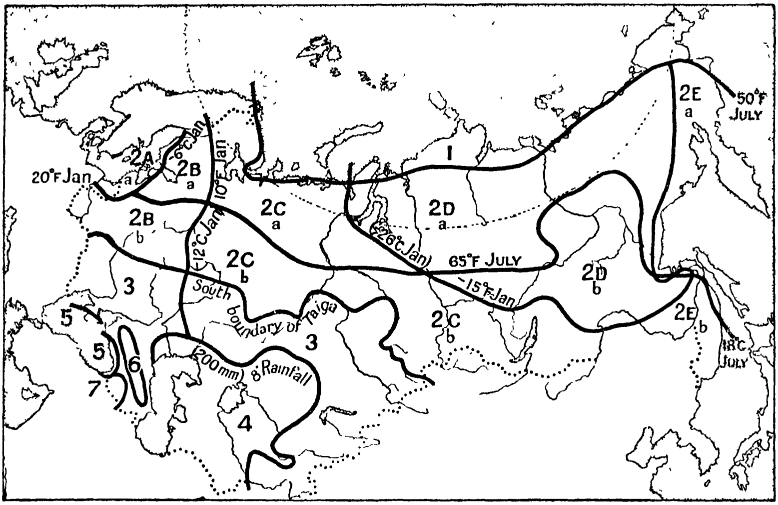


FIG. 92. Major climatic regions of the U.S.S.R.

differences in the intensity of the winter cold, great as they are, are probably of no very great importance for plant-life once the January mean is below 10° F.

The 65° isotherm for July, which has a generally east-to-west trend, separates a northern subdivision (*a*), with mean July temperature between 50° and 65°, and a southern (*b*), with July temperature above 65°.

2 (A). The Baltic coast has a mild winter, the January mean being over 20°, and a somewhat cool summer, the July mean being under 65°; the warmer subdivision (*b*) does not appear here. The precipitation exceeds 20 inches per annum, autumn having most. The depressions of the westerlies exercise an important control on the weather.

2 (B). West-central Russia with colder winters.

2 (C). East Russia and west Siberia with very cold winters

indeed, the January mean being 10° in the west, −15° in the east. Precipitation is 20 inches per annum on the west of the Urals, only 8 to 16 inches on the east; the northern subdivision (*a*) has less than (*b*).

2 (D). Central Siberia has the coldest winters known near sea-level, and an extreme range of temperature. The air is dry and clear in winter, and the sky much less cloudy than in 2 (C). The precipitation is low, 8 to 12 inches.

2 (E). The east coast is distinguished chiefly by its damp, cloudy, cool summer with fog and drizzle. Winter is cold, but less than in the interior, with almost constant NW. winds, strongest where a mountain shelter is lacking; Nikolayevsk is 5° colder in January than Ayan, almost 4° of latitude farther north, owing to the winds which sweep down the Amur valley. The sky is very clear and precipitation scanty. Autumn is the driest and most pleasant season. The Amur basin has very heavy rain in summer and the ground is waterlogged; the winters, owing to the strong wind, are more trying than in the far interior of Siberia, and altogether the climate is much less healthy and agreeable.

3. The boundary between this region and 2 is the line (or belt) separating the taiga from the steppes. In the steppes the precipitation is from 8 to 16 inches, which is the more scanty in view of the dry air and the heat of summer. The rainy season is spring and early summer, when much of the rain falls in heavy thunderstorms, so that the run-off is excessive and most of the water is lost to vegetation, only the surface of the soil being moistened. The prevailing winds are NE., strong and dry throughout the year; in winter they often blow with gale force in the buran. Nearly all the snow that falls is swept away by the wind and the ground is left bare, exposed to the full rigour of the winter frost, which is very severe. But the coast has cyclonic weather, southerly winds bringing warmth and humidity in great contrast to the dry cold of the bitter north-easters. Summer is hot, and spring is as warm as, or warmer than, autumn. Thus all factors combine to make a climate unfavourable to tree-growth, and grass is the natural vegetation.

We may subdivide 3 into a western division with a mean

January temperature above 10°, and an eastern with a mean below 10°.

4. Towards the south precipitation continues to decrease, and in region 4 the annual mean is below 8 inches. A border of scanty grass surrounds the bare sand-dunes of the deserts of Uzbek with precipitation less than 4 inches. The winters are very cold for the latitude, with means far below freezing-point except in the extreme south. The summers are very hot indeed, the July mean exceeding 85° in the south. The air is dry and the sky almost cloudless.

5. The south of the Crimea has mild rainy winters (mean January temperature above freezing-point) and hot sunny dry summers; the vegetation approaches the Mediterranean type. The eastern shores of the Black Sea have excessive rain all the year. In winter the fierce bora may sweep down with temperatures well below freezing-point at the foot of the Caucasus.

6. The Caucasus climate of the mountain type.

7. Includes high plateau, with very cold winters and hot summers, but also much low ground. Precipitation is heavy, and tea is important in Georgia and Azerbaijan, an interesting contrast to the wheat on the opposite side of the Black Sea.

CLIMATIC MEANS

TEMPERATURE (°F.)

The Indian Region. Ceylon. Burma

	Alt. feet	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*	*Range*
Colombo	24	*79*	79	81	82	**82**	81	81	81	81	80	79	79	81	3
Trincomalee	30	*78*	79	81	83	85	85	**85**	85	84	82	79	78	82	7
Cochin	98	80	81	83	**84**	83	79	*78*	78	79	79	80	80	80	6
Bombay	37	*75*	75	78	82	**85**	83	80	*80*	80	**81**	80	77	79	10
Poona	1,846	70	74	80	**84**	84	79	75	*74*	74	**76**	73	*69*	76	15
Bangalore	3,021	67	72	77	**80**	79	74	72	72	72	72	70	*67*	73	13
Madras	22	*77*	78	81	85	90	**90**	87	86	85	82	79	77	83	13
Akyab	20	*70*	73	79	83	**85**	81	81	81	81	81	78	72	79	15
Rangoon	18	*77*	79	83	**87**	85	81	81	*81*	81	**82**	80	77	81	10
Mandalay	250	*69*	74	82	**89**	89	85	85	85	83	83	76	69	81	20
Calcutta	21	*67*	71	80	85	**87**	85	84	83	83	81	73	67	79	20
Patna	183	*61*	65	77	86	**88**	86	83	83	83	79	70	62	77	27
Benares	267	*60*	65	77	87	**91**	89	84	83	83	78	68	60	77	31
Allahabad	309	*59*	65	77	88	**93**	91	85	83	83	78	67	60	77	34
Cawnpore	416	*59*	64	75	87	**93**	91	86	83	83	77	68	60	77	34
Delhi	718	*58*	62	74	86	92	**92**	86	85	84	79	68	60	77	34
Jaipur	1,431	*60*	64	75	86	**92**	91	85	82	82	78	69	61	77	32
Hoshangabad	1,006	66	70	80	90	**93**	88	80	78	79	77	71	*65*	78	28
Pachmarhi	3,528	*57*	62	74	82	**84**	78	72	69	71	68	62	57	70	27
Lahore	702	*53*	57	69	81	89	**93**	89	87	85	76	63	55	75	40
Mooltan	420	*56*	60	72	82	91	**95**	93	90	88	79	67	58	77	39
Jacobabad	186	*57*	62	75	85	94	**98**	95	92	89	79	67	59	79	41
Karachi	13	*67*	69	74	78	83	**85**	83	81	80	79	75	68	77	18

TEMPERATURE (°F.) (*continued*)

The Indian Region, Ceylon, Burma (continued)

	Alt. feet	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year	Range
Peshawar	1,113	*50*	53	63	73	84	**91**	90	88	82	71	59	51	71	41
Darjeeling	7,376	*40*	42	50	56	58	60	**61**	61	59	55	48	42	53	21
Simla	7,232	*39*	41	51	59	66	**67**	64	63	61	57	50	43	55	28
Srinagar	5,204	*31*	33	45	56	64	70	**73**	71	64	53	44	36	53	42
Leh	11,503	*17*	19	31	43	50	58	**63**	61	54	43	32	22	41	45
China. Korea															
Harbin	526	*−1*	6	24	43	57	67	**73**	70	58	40	21	4	39	74
Mukden	141	*11*	17	32	49	62	73	**78**	76	63	49	31	15	47	67
Dairen	314	*23*	26	36	49	60	69	75	**77**	69	57	41	28	51	54
Peking	125	*25*	29	42	56	69	75	**80**	77	70	56	39	29	54	55
Yangku (Taiyuan)	2,641	*19*	27	38	54	65	73	**78**	74	64	51	37	25	51	59
Changan (Sianfu)	1,197	*31*	37	51	63	73	83	**85**	83	73	61	47	36	61	54
Chengtu	1,611	*43*	47	53	63	71	77	**79**	79	71	63	54	47	62	36
Chungking	755	*45*	50	59	67	73	77	84	**85**	75	65	57	51	66	40
Hankow	121	*40*	43	50	62	71	80	**86**	86	77	67	55	45	63	46
Nanking	34	*36*	39	47	58	69	76	**81**	81	73	63	51	40	59	45
Shanghai	23	*38*	39	46	56	66	73	**81**	81	73	63	53	42	59	43
Wenchow	14	*47*	47	53	62	70	77	83	**83**	78	69	60	52	65	36
Tengchung (Tengyueh)	5,360	*48*	49	55	59	65	68	**69**	69	67	62	55	49	60	21
Kunming	6,201	*49*	52	57	63	67	69	**70**	69	67	61	55	50	61	21
Wuchow	36	*53*	56	63	72	79	82	83	**84**	81	73	67	60	71	31
Swatow	10	*57*	57	61	69	77	81	83	**84**	81	75	68	62	71	27
Canton	29	*57*	56	63	72	80	83	84	**85**	82	75	68	62	73	28
Hong Kong	109	*60*	59	63	70	77	81	**82**	82	81	76	69	63	72	22
Taihoku (Formosa)	30	59	*58*	63	69	75	80	**83**	82	79	73	67	62	71	25
Wonsan (Gensan), Korea	120	*26*	27	36	49	59	66	73	**74**	66	55	42	30	50	48
Inchon (Chemulpo), Korea	231	*25*	28	37	49	59	67	74	**77**	68	57	43	30	51	52

Japan

	Alt. feet	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year	Range
Nemuro	89	23	*22*	28	37	44	50	57	**63**	59	51	40	29	42	41
Sapporo	55	*21*	22	29	41	51	58	66	**69**	61	49	37	26	44	48
Ishinomaki	147	*32*	33	37	48	55	63	70	**73**	67	57	46	36	51	41
Niigata	85	*35*	35	40	50	59	67	75	**78**	70	59	49	39	55	43
Tokyo	19	*39*	39	45	55	62	70	76	**79**	73	61	51	42	57	40
Osaka	10	41	*40*	45	56	64	71	80	**82**	75	63	53	44	59	42
Hiroshima	10	*40*	40	45	55	63	70	78	**80**	73	62	52	43	58	40
Nagasaki	436	*43*	43	49	58	65	71	78	**81**	75	65	55	47	61	38
Kagoshima	18	*45*	45	51	60	66	72	78	**80**	75	66	57	48	62	35

Indonesia. South-east Asia

	Alt. feet	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year	Range
Hanoi	46	62	*61*	68	74	80	**84**	84	83	81	78	70	64	74	23
Bangkok	14	79	81	85	**87**	86	85	84	84	83	83	80	*78*	83	9
Manila	47	*78*	79	81	83	**85**	83	81	81	81	81	79	78	81	7
Penang	17	81	82	**83**	83	82	82	82	81	*81*	81	81	81	82	2
Singapore	16	*78*	78	79	80	**81**	80	80	80	79	80	79	78	79	3
Jakarta (Batavia)	26	*78*	78	78	79	**79**	79	78	79	79	79	79	78	79	1
Port Moresby	126	83	81	82	81	81	79	78	*77*	79	81	82	**83**	81	6
Koepang	148	80	80	80	80	79	78	*77*	78	80	81	**82**	81	80	5

The Heart of Asia

	Alt. feet	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year	Range
Kashgar	4,296	*23*	31	46	60	70	77	**80**	78	70	57	41	27	55	57
Lukchun	−100 (approx.)	*13*	27	45	66	75	85	**91**	85	74	55	33	21	56	78
Tihwa (Urumtschi)	2,913	*4*	8	24	46	59	68	**72**	68	60	43	24	9	40	68
Uliassutai (Jibhalanta)	5,640	*−10*	−1	11	33	46	53	**60**	57	45	29	6	6	27	70
Ulan Bator (Urga)	4,347	*−11*	−3	12	33	46	58	**63**	60	47	31	8	6	28	74

TEMPERATURE (°F.) (*continued*)

	Alt. feet	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year	Range
Tibet															
Lhasa (see p. 239)	12,090	*32*	34	43	49	56	**63**	61	60	59	48	40	33	48	31
South-west Asia															
Turkey, Cyprus															
Samsun	131	44	*43*	47	52	60	67	72	**74**	69	62	55	49	58	31
Izmir	33	*46*	47	53	59	68	76	**81**	80	73	66	57	50	63	36
Adana	46	*48*	50	56	63	71	78	82	**83**	78	71	60	51	66	35
Ankara	2,789	*31*	33	42	51	61	67	**73**	73	65	56	46	35	53	42
Sivas	4,167	*22*	27	37	46	56	63	66	**67**	60	51	40	28	47	45
Erzurum	6,168	*12*	18	23	40	52	59	**66**	65	59	48	34	20	41	54
Kyrenia (Cyprus)	45	*53*	55	58	64	71	78	83	**84**	79	73	63	57	68	31
Syria, Israel															
Aleppo	1,312	*42*	45	51	61	69	77	88	**89**	77	67	51	49	65	47
Damascus	2,264	*44*	46	53	59	69	78	**82**	76	72	65	56	47	62	38
Palmyra	1,329	*45*	49	56	67	75	81	**85**	85	79	71	59	47	67	40
El Kareya	3,330	*41*	45	48	56	65	68	71	**72**	67	63	53	46	58	31
Haifa	52	*57*	58	62	67	74	78	82	**83**	81	76	69	60	71	26
Jerusalem	2,485	*47*	48	55	61	69	73	75	**75**	73	69	62	52	63	28
Jericho	—820	*57*	59	65	72	80	85	88	**88**	85	80	71	60	74	31
Arabia															
Aden	123	*79*	81	82	86	89	**92**	88	88	89	85	83	80	85	13
Jidda	20	73	*72*	77	80	83	85	87	**88**	86	83	80	76	81	16
Iraq															
Mosul	730	*44*	48	55	63	75	84	**91**	91	82	71	59	47	67	47
Baghdad	110	*48*	52	61	71	82	90	**94**	94	87	76	63	52	73	46
Rutba	2,020	*44*	49	56	65	74	81	86	**87**	80	71	58	47	66	43
Basra	60	*52*	57	65	75	86	91	96	**97**	90	80	68	55	76	45

South-west Asia (continued)

Persia (Iran)	*Alt. feet*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*	*Range*
Lenkoran (Azerbaijan) .	−66	*38*	41	46	54	65	74	**78**	78	71	62	51	43	58	40
Tehran . . .	4,002	*35*	41	49	60	70	80	**85**	84	77	64	53	42	62	50
Isfahan . . .	5,817	*35*	41	49	59	69	77	**83**	80	73	61	50	41	60	48
Abadan . . .	7	*53*	59	65	76	87	93	**97**	97	90	81	69	58	77	44
Jask	13	*67*	69	74	80	85	90	**91**	89	87	83	76	71	80	24
Bushire . . .	14	*57*	59	66	74	83	87	89	**91**	87	80	71	61	75	34
Afghanistan, Baluchistan															
Kabul . . .	6,250	*31*	36	47	59	68	73	**77**	75	69	58	51	40	57	46
Quetta . . .	5,500	*40*	41	51	59	67	74	**78**	75	67	56	47	42	58	38
Seistan . . .	2,000	*45*	46	51	61	72	81	**81**	78	71	63	55	45	62	36

U.S.S.R. (Russia, &c.)

	Alt. feet	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*	*Range*
Archangel . . .	50	*8*	10	17	30	41	53	**59**	55	46	34	21	12	32	51
Kola	33	11	*11*	17	29	38	48	**55**	51	43	31	21	13	31	44
Leningrad . . .	30	18	*18*	25	37	49	58	**63**	60	51	41	30	22	39	45
Mariehamn (Åland Is.) . .	30	27	*25*	27	35	44	54	**59**	58	51	43	36	30	41	34
Riga	50	*24*	25	30	41	53	60	**64**	61	53	43	34	27	43	40
Kaliningrad (Königsberg)	62	*27*	29	33	42	53	60	**63**	61	55	46	36	30	45	36
Moscow . . .	480	*14*	17	25	39	55	61	**66**	62	51	40	28	19	40	52
Kazan . . .	250	*7*	11	21	38	55	63	**68**	63	52	38	24	13	38	61
Kiev	590	*21*	23	31	44	58	63	**67**	65	56	45	33	26	44	46
Saratov . . .	295	*11*	15	24	41	59	67	**72**	69	57	43	29	18	42	61
Orenburg (Chkalov) . .	360	*4*	8	19	39	59	67	**72**	67	55	40	24	12	39	68
Odessa . . .	210	*26*	29	37	47	60	68	**73**	71	62	52	40	32	50	47

TEMPERATURE (°F.) (*continued*)

Russia (continued)

	Alt. feet	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year	Range
Yalta	135	39	39	43	51	61	69	75	75	66	58	48	43	56	36
Batumi	20	43	44	47	52	60	68	73	74	68	61	54	48	58	31
Baku	0	38	39	43	51	63	72	77	77	71	62	51	44	57	39
Astrakhan	−50	19	23	33	48	64	73	77	74	63	49	36	27	49	58
Tiflis	1,350	32	37	44	53	62	70	76	76	67	57	45	37	54	44
Kars	5,725	9	13	24	39	49	57	63	64	56	45	31	18	39	55
Turt-Kul (Petro-Alexandrowsk)	295	23	29	42	58	71	79	82	78	67	52	40	30	54	59
Samarkand	2,362	32	36	46	57	66	74	77	74	65	53	45	38	55	45
Tashkent	1,610	30	35	46	58	68	77	80	76	66	54	45	37	56	50
Pamirski Post	11,985	1	5	20	33	43	50	56	56	46	32	19	4	30	55
Irgis	360	4	7	19	43	62	73	77	73	60	43	25	12	41	73
Semipalatinsk	590	3	4	14	37	58	67	71	67	56	38	21	9	37	68
Tobolsk	340	−3	4	16	32	48	59	64	60	49	32	14	3	31	67
Berezov	100	−11	−1	9	23	37	51	60	55	43	26	6	−5	24	71
Tomsk	390	−3	2	13	30	47	59	64	59	48	32	13	2	31	67
Irkutsk	1,532	−6	0	15	34	47	58	64	59	47	33	13	−1	30	70
Chita	2,218	−17	−7	10	32	46	60	66	60	47	29	6	−12	27	83
Verkhoyansk	330	−58	−48	−22	8	35	54	59	51	36	6	−34	−52	3	117
Bulun	115	−42	−32	−15	4	25	45	53	48	36	10	−22	−34	6	95
Petropavlovsk	286	17	16	21	30	37	46	52	55	49	39	27	19	34	39
Okhotsk	30	−13	−5	6	21	33	42	53	55	47	28	4	−7	22	68
Blagoveshchensk	466	−9	−1	15	36	51	63	71	69	54	37	11	−8	33	80
Vladivostok	420	6	14	27	40	49	57	65	69	62	49	30	14	40	63

PRECIPITATION (inches)

The Indian Region. Ceylon. Burma

	Alt. feet	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*
Colombo	24	4·0	*2·2*	4·9	8·9	**15·0**	9·0	6·0	*2·6*	7·0	**13·3**	12·3	5·6	90·8
Trincomalee	30	8·7	2·0	2·4	2·0	3·4	*1·1*	1·9	3·5	3·8	9·1	**14·3**	12·6	64·8
Cochin	98	*0·7*	0·8	2·0	4·7	11·7	**28·5**	22·8	12·9	9·0	13·2	6·5	1·7	114·5
Bombay	37	0·1	0·1	0·1	0·1	0·8	18·3	**24·3**	13·8	10·5	2·2	0·4	*0·1*	70·6
Poona	1,846	0·1	*0·1*	0·1	0·6	1·2	4·8	**7·0**	3·7	4·8	3·7	1·0	0·2	27·1
Bangalore	3,021	0·3	*0·2*	0·5	1·3	4·4	2·9	4·2	5·4	**7·0**	5·9	2·9	0·5	35·4
Madras	22	1·4	0·3	*0·2*	0·5	1·1	1·9	3·9	4·6	5·0	11·7	**14·3**	5·8	50·7
Tuticorin	30	1·1	0·6	1·0	1·6	0·9	0·2	*0·1*	0·3	0·6	5·3	**7·1**	3·2	21·9
Akyab	20	*0·1*	0·1	0·5	2·1	13·9	46·9	**54·8**	45·2	22·6	10·9	5·5	0·8	203·4
Rangoon	18	*0·2*	0·2	0·3	1·6	12·0	18·0	**21·4**	20·0	15·3	6·9	2·8	0·3	99·0
Mandalay	250	*0·1*	0·1	0·2	1·1	**5·9**	5·5	*3·3*	4·6	**5·7**	4·7	1·6	0·4	33·2
Calcutta	21	0·3	1·1	1·4	1·9	5·7	11·9	12·5	**12·7**	9·9	4·2	0·7	*0·2*	62·5
Dacca	35	0·3	1·3	2·6	5·4	9·7	13·6	12·8	**13·1**	9·8	4·6	0·8	*0·2*	74·2
Cherrapunji	4,309	0·5	3·0	9·8	31·8	47·6	92·8	**100·1**	82·5	35·2	21·9	2·9	*0·4*	428·4
Shillong	4,920	0·4	0·8	1·9	4·7	10·1	**16·2**	13·4	13·0	12·8	6·4	1·2	*0·3*	81·1
Gopalpur	21	*0·3*	0·6	0·5	0·8	1·9	5·6	6·1	7·3	7·3	**8·5**	3·7	0·7	43·3
Raipur	970	0·4	0·7	0·7	0·7	1·0	9·5	**14·3**	13·3	7·4	2·0	0·4	*0·2*	50·4
Patna	183	0·5	0·7	0·5	0·3	1·7	8·1	11·9	**13·5**	8·3	2·5	0·3	*0·1*	48·5
Benares	267	0·7	0·6	0·4	*0·2*	0·6	4·8	**12·1**	11·6	7·1	2·1	0·2	*0·2*	40·6
Allahabad	309	0·8	0·6	0·3	0·1	0·3	5·0	**11·7**	11·7	5·7	2·3	0·3	*0·2*	39·1
Cawnpore	416	0·6	0·5	0·3	*0·2*	0·4	3·1	9·7	**10·2**	5·5	1·2	*0·2*	0·3	32·1
Delhi	718	1·0	0·8	0·5	0·4	0·6	3·0	**7·5**	7·4	4·8	0·3	*0·1*	0·4	26·8
Jaipur (Rajputana)	1,431	**0·4**	0·3	0·4	*0·2*	0·6	2·6	**8·3**	7·3	3·2	0·3	*0·1*	0·3	24·0
Lahore	702	**1·1**	0·9	0·9	*0·5*	0·7	1·7	**5·5**	5·3	2·4	0·3	*0·1*	0·4	19·6
Mooltan	420	0·4	0·3	**0·4**	*0·3*	0·3	0·5	**1·9**	1·7	0·6	0·1	*0·1*	0·2	6·8
Jacobabad	186	0·3	**0·3**	0·3	0·2	*0·1*	0·2	1·0	**1·1**	0·3	*0*	0·1	0·1	4·0

PRECIPITATION (inches) (*continued*)

The Indian Region. Ceylon. Burma (continued)

	Alt. feet	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Karachi	13	**0·5**	0·4	0·3	0·2	*0·1*	0·9	**2·9**	1·7	0·4	0	*0*	0·1	7·5
Peshawar	1,113	1·6	1·3	**2·3**	1·9	0·8	*0·4*	1·2	**2·2**	0·8	*0·2*	0·3	0·6	13·5
Darjeeling	7,376	0·5	1·1	1·8	3·9	8·7	24·9	**32·3**	26·1	18·4	4·5	0·8	*0·2*	123·3
Simla	7,232	2·5	2·7	2·7	2·3	2·8	7·3	17·0	**17·4**	5·9	1·0	*0·5*	1·0	63·1
Srinagar	5,204	2·7	2·8	3·6	**3·8**	2·3	*1·5*	2·2	**2·3**	1·6	1·2	*0·4*	1·5	25·7
Chitral	5,486	1·2	1·6	3·2	**3·9**	0·7	0·3	*0·1*	0·2	0·2	0·7	0·3	0·9	13·3
Leh	11,503	**0·4**	0·3	0·3	0·2	*0·2*	0·2	0·5	**0·5**	0·3	0·2	*0*	0·2	3·2

China. Korea

	Alt. feet	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Harbin	526	*0·2*	0·2	0·4	0·9	1·7	3·7	**4·4**	4·1	1·8	1·3	0·3	0·2	19·2
Mukden	141	*0·3*	0·3	0·7	1·1	2·7	3·3	**7·2**	6·7	2·5	1·4	1·1	0·6	27·9
Dairen	314	0·5	*0·3*	0·7	0·9	1·7	1·8	**6·4**	5·1	4·0	1·1	0·9	0·5	23·9
Peking	125	*0·1*	0·2	0·2	0·6	1·5	3·4	**8·3**	6·1	2·5	0·7	0·3	0·1	24·1
Yangku (Taiyuan)	2,641	0·1	0·1	0·1	0·4	1·1	2·2	**4·6**	4·4	1·7	0·5	*0*	0·1	15·3
Changan (Sianfu)	1,197	*0·3*	0·3	0·7	1·8	1·9	1·8	3·9	**3·9**	2·3	1·6	0·5	0·3	19·3
Chengtu	1,611	*0·2*	0·4	0·6	1·9	2·4	4·5	8·7	**11·5**	6·3	2·1	0·5	0·2	39·3
Chungking	755	*0·7*	0·9	1·4	3·8	5·5	**6·7**	5·2	4·3	5·8	4·5	1·9	0·8	41·5
Hankow	121	1·8	1·9	3·8	6·0	6·5	**9·6**	7·1	3·8	2·8	3·2	1·9	*1·1*	49·5
Nanking	34	1·6	2·0	3·0	4·0	3·2	7·2	**8·1**	4·6	3·7	2·0	1·6	*1·2*	42·2
Shanghai	23	1·9	2·3	3·3	3·7	3·7	**7·1**	5·8	5·6	5·1	2·8	2·0	*1·4*	44·7
Wenchow	14	1·9	3·5	5·0	5·7	7·3	**10·3**	7·8	10·0	8·4	3·5	2·2	*1·7*	67·3
Tengchung (Tengyueh)	5,360	*0·5*	1·5	1·6	2·9	5·0	9·6	**13·3**	10·9	7·4	7·1	1·9	0·7	62·4
Kunming	6,201	*0·4*	0·5	0·7	0·8	4·3	6·3	**8·8**	8·6	5·0	3·0	1·7	0·4	40·5
Wuchow	36	*1·3*	2·2	3·8	6·3	**8·1**	7·6	6·3	7·0	3·3	1·7	1·5	1·5	50·6
Swatow	10	*1·4*	2·3	3·3	5·7	8·5	**10·1**	8·1	8·4	5·2	2·4	1·7	1·5	58·6
Canton	29	*1·3*	2·4	4·3	5·5	9·3	**11·6**	10·5	6·7	5·9	1·1	0·7	1·9	61·2
Hong Kong	109	1·3	1·7	2·9	5·4	11·5	**15·5**	15·0	14·2	10·1	4·5	1·7	*1·1*	84·9

China. Korea (continued)

	Alt. feet	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Wonsan (Gensan), Korea	120	1·4	1·5	1·9	2·8	3·5	4·8	11·2	**12·4**	7·1	3·1	2·7	*1·1*	53·5
Inchon (Chemulpo), Korea . . .	231	0·8	*0·7*	1·2	2·6	3·3	3·9	**10·9**	8·8	4·3	1·6	1·6	1·1	40·8
Japan														
Hakodate . . .	13	2·5	*2·3*	2·6	2·7	3·2	3·7	5·2	5·1	**6·5**	4·8	3·9	3·1	45·6
Niigata . . .	85	7·6	5·0	4·3	4·2	*3·6*	5·2	6·3	4·9	**7·6**	*6·1*	7·3	**9·3**	71·4
Kanazawa . . .	94	10·4	7·6	6·7	6·1	*5·6*	7·3	8·5	6·3	**10·6**	*8·5*	10·9	**13·4**	101·8
Ishinomaki . . .	147	*1·8*	2·1	3·0	3·6	4·6	4·8	5·0	5·0	**6·9**	5·0	2·6	1·8	46·2
Tokyo . . .	19	*2·2*	2·6	4·4	5·2	6·0	**6·4**	*5·5*	6·4	**8·9**	7·5	4·1	2·2	61·4
Kobe	191	1·9	2·2	3·6	5·0	4·9	**8·2**	6·0	*4·6*	**7·7**	4·8	2·6	*1·9*	53·4
Hiroshima . . .	10	*2·1*	2·4	4·3	6·8	5·9	**9·4**	8·0	*4·4*	**7·3**	4·4	2·7	2·1	59·8
Nagasaki . . .	436	*3·0*	3·3	5·2	7·5	6·7	**12·8**	9·4	*6·8*	**8·6**	4·8	3·5	3·4	75·0
Kagoshima . . .	18	*3·4*	4·0	6·4	8·7	8·2	**17·0**	12·2	*7·4*	**8·7**	5·2	3·7	3·4	88·3
Indonesia. South-east Asia (see pp. 221–226).														
The Heart of Asia														
Kashgar . . .	4,296	0·3	0·1	**0·4**	*0·2*	0·4	0·3	0·3	**0·4**	0·2	*0·1*	0·2	0·2	2·9
Ulan Bator (Urga) .	4,347	0·1	*0·1*	0·2	0·2	0·4	1·6	**2·4**	2·1	0·7	0·1	*0·1*	**0·3**	8·1
Tihwa (Urumtschi) .	2,913	0·6	*0·2*	0·5	1·1	1·2	**1·5**	*0·5*	0·8	0·9	**1·5**	0·6	0·5	9·9
Tibet														
Lhasa (see p. 239) . .	12,090	0	0·1	0·3	0·2	5·1	6·3	**25·8**	17·8	7·2	0·3	0	0	63·0
South-west Asia														
Turkey, Cyprus														
Samsun . . .	131	2·9	2·5	2·5	2·3	1·8	1·5	1·4	*1·1*	2·3	2·9	**3·7**	3·2	28·1
Izmir	33	4·2	3·6	3·0	1·6	1·4	0·4	0·2	*0·1*	0·8	1·7	3·1	**4·9**	25·0
Adana . . .	46	3·2	3·2	2·6	1·9	2·0	0·9	0·3	*0·3*	0·6	1·3	3·0	**4·5**	23·8
Ankara . . .	2,789	0·7	0·9	1·0	0·9	**1·8**	1·0	*0·3*	0·4	0·4	0·4	0·7	1·6	10·1

PRECIPITATION (inches) (*continued*)

South-west Asia (continued)

	Alt. feet	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Sivas	4,167	1·4	1·4	1·2	2·1	2·0	1·1	0·2	*0·2*	0·9	1·0	1·7	1·3	14·5
Erzurum	6,168	0·6	1·6	1·4	2·1	2·9	2·3	1·3	*0·6*	1·4	1·6	1·2	1·3	18·3
Kyrenia (Cyprus)	45	4·6	3·2	2·4	0·8	1·0	0·2	0	*0*	0·2	1·3	3·8	4·9	22·4
Syria, Lebanon, Israel														
Beirut	121	7·3	6·4	3·5	2·2	0·6	0·1	*0*	0	0·2	1·9	5·1	7·5	34·8
Aleppo	1,312	3·0	2·8	1·0	1·3	0·4	0·1	*0*	0·1	0	0·8	2·4	3·2	15·1
Damascus	2,264	1·7	2·1	0·4	0·5	0·2	0	0	0	0·7	0·4	1·6	1·6	9·2
Palmyra	1,329	1·0	0·8	0·2	0·5	0·3	0	0	0	0	0·3	0·3	1·1	4·5
El Kareya	3,330	11·1	13·7	7·7	3·7	1·4	0·3	*0*	0	0·3	2·0	6·5	10·0	56·7
Haifa	52	7·1	5·7	0·9	0·7	0·1	0	0	0	0	0·5	2·7	6·7	24·4
Jerusalem	2,485	4·1	5·3	1·1	1·0	0·1	0	0	0	0	0·2	1·2	2·9	15·9
Jericho	−820	1·3	1·3	0·2	0·4	0·1	0	0	0	0	0·1	0·4	1·2	5·0
Arabia														
Aden	123	0·2	0·7	0·6	0	0	0	0	0	0·4	0·2	0	0·2	2·3
Jidda	20	0·9	0	0	0	0	0	0	0	0	0	1·6	0·6	3·1
Iraq														
Mosul	730	2·1	3·0	1·6	1·8	0·5	0	0	0	0	0·2	1·8	2·0	13·0
Baghdad	110	1·2	1·1	0·3	0·4	0·4	0	0	0	0	0·1	1·0	1·0	5·5
Rutba	2,020	0·9	0·7	0·1	0·4	0·2	0	0	0	0	0·1	0·7	0·7	3·8
Basra	60	1·3	1·2	0·4	0·5	0·1	0	0	0	0	0·1	1·1	1·0	5·7
Iran (Persia)														
Pahlevi	−67	2·3	1·9	3·2	1·2	1·6	2·0	*0·7*	1·7	7·5	11·0	8·0	3·0	44·1
Tehran	4,002	1·7	1·0	1·9	1·1	0·4	0·1	0·2	*0*	0·1	0·3	1·1	1·3	9·2

South-west Asia (continued)

Iran (Persia) (cont.)	Alt. feet	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*
Isfahan	5,817	0·6	0·4	**1·0**	0·6	0·2	0	0	0	0	0·1	0·6	0·8	4·4
Abadan	7	1·5	1·7	0·6	0·8	0·1	0	0	0	0	0·1	1·0	**1·8**	7·6
Jask	13	**1·2**	0·9	0·6	0·2	0	0·1	0·1	0	0	0·2	0·3	1·2	4·7
Bushire	14	2·9	1·8	0·8	0·4	0·1	0	0	0	0	0·1	1·6	**3·1**	10·9
Afghanistan, Baluchistan														
Quetta	5,500	**1·9**	1·9	1·8	0·9	0·3	*0·2*	0·3	**0·3**	< *0·1*	0·1	0·4	1·1	9·4
Seistan	2,000	0·4	0·4	**0·5**	0·1	0	0	0	0	0	0	0	0·3	1·7

U.S.S.R. (Russia, &c.)

	Alt. feet	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*
Archangel	50	0·9	*0·7*	0·8	0·7	1·2	1·8	2·4	**2·4**	2·2	1·6	1·2	0·9	16·8
Kola	33	0·3	0·3	*0·2*	0·3	0·6	0·7	**1·4**	1·3	1·0	0·8	0·6	0·3	7·8
Leningrad	30	0·9	*0·8*	0·9	0·9	1·7	1·8	2·7	**2·7**	2·0	1·7	1·4	1·2	18·8
Riga	50	1·3	1·3	*1·1*	1·5	1·6	2·5	**3·5**	3·3	2·0	1·9	2·0	1·6	23·9
Kaliningrad (Königsberg)	62	1·7	1·5	*1·5*	1·5	1·9	2·4	3·3	**3·3**	3·0	2·4	2·3	2·2	27·4
Moscow	480	1·1	*0·9*	1·2	1·5	1·9	2·0	2·8	**2·9**	2·2	1·4	1·6	1·5	21·0
Kazan	250	0·5	*0·4*	0·6	0·9	1·6	2·2	**2·4**	2·4	1·6	1·1	1·0	0·7	15·4
Kiev	590	1·1	*0·8*	1·5	1·7	1·7	2·4	**3·0**	2·4	1·7	1·7	1·5	1·5	21·1
Simferopol	853	1·2	*1·1*	1·4	1·3	1·5	**2·2**	2·0	1·3	1·5	1·1	1·3	1·6	17·5
Saratov	295	0·9	0·8	*0·7*	1·1	1·1	1·5	**1·7**	1·3	1·2	1·5	1·4	1·6	14·9
Orenburg (Chkalov)	360	1·1	*0·8*	1·0	0·9	1·4	**2·0**	1·7	1·3	1·3	1·2	1·2	1·2	15·2
Odessa	210	0·9	*0·7*	1·1	1·1	1·3	**2·3**	2·1	1·2	1·4	*1·1*	**1·6**	1·3	16·1
Astrakhan	−50	0·5	*0·3*	0·4	0·5	0·6	**0·7**	0·5	0·5	0·5	0·4	0·4	0·5	5·9
Yalta	135	1·8	1·6	1·6	1·3	1·1	1·5	1·3	*0·9*	1·4	1·7	2·0	**3·0**	19·9
Batumi	30	10·2	6·0	6·2	5·0	*2·8*	5·9	6·0	8·2	**11·9**	*8·8*	**12·2**	10·0	93·3
Baku	0	**1·3**	0·9	0·8	0·8	0·6	0·3	*0·2*	0·2	0·8	1·2	1·2	1·2	9·5
Tiflis	1,350	*0·6*	0·8	1·1	2·1	**2·9**	2·7	2·1	1·6	2·0	1·3	1·1	0·8	19·1
Kars	5,725	*0·7*	0·7	1·1	1·7	**2·7**	1·9	1·7	1·3	1·1	1·3	1·2	0·8	16·3

PRECIPITATION (inches) (*continued*)

U.S.S.R. (*Russia, &c.*) (continued)

	Alt. feet	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Krasnovodsk	−66	*0·5*	0·6	0·7	**1·0**	0·5	0·6	*0·2*	0·3	0·3	0·5	**0·6**	0·5	6·3
Turt-Kul (Petro-Alexandrowsk)	295	0·2	0·4	0·5	**0·6**	0·2	0	0	0·1	0	0·1	0·1	0·1	2·4
Merv	755	1·8	1·4	**2·1**	1·2	0·1	0	0	0	0	0·4	0·1	0·4	7·5
Tashkent	1,610	1·8	1·4	**2·6**	2·6	1·1	0·5	0·1	*0·1*	0·2	1·1	1·4	1·7	14·6
Irgis	360	0·6	*0·3*	0·5	0·7	0·8	**0·9**	0·6	0·4	0·5	0·5	0·4	0·7	6·9
Semipalatinsk	590	0·5	*0·2*	0·4	0·4	0·8	0·9	**1·1**	0·4	0·6	0·6	0·6	0·8	7·3
Barnaul	480	0·8	0·6	*0·6*	0·6	1·3	1·7	**2·2**	1·8	1·1	1·3	1·1	1·1	14·2
Tobolsk	340	0·7	*0·6*	0·7	0·8	1·3	2·7	**3·5**	3·2	1·5	1·4	1·3	0·9	18·6
Berezovo	100	1·0	0·6	0·8	1·3	1·6	2·2	**3·4**	2·3	2·3	1·1	1·3	*0·5*	18·4
Tomsk	390	1·1	0·8	0·8	*0·7*	1·5	2·7	**3·0**	2·3	1·4	2·4	1·4	1·9	19·9
Irkutsk	1,532	0·5	0·4	*0·3*	0·6	1·3	2·2	**3·1**	2·8	1·7	0·7	0·6	0·6	14·9
Verkhoyansk	330	0·2	0·1	*0*	0·1	0·2	0·5	**1·2**	0·9	0·2	0·2	0·2	0·2	3·9
Chita	2,218	*0·1*	0·1	0·1	0·4	1·1	1·8	3·3	**3·3**	1·2	0·5	0·2	0·2	12·3
Blagoveshchensk	466	*0·1*	0·1	0·3	0·9	1·6	3·3	4·4	**4·5**	2·7	0·7	0·3	0·1	19·0
Okvotsk	30	0·1	*0·1*	0·1	0·2	0·5	1·1	0·5	1·8	**2·1**	0·7	0·2	0·2	7·5
Vladivostok	420	*0·3*	0·4	0·7	1·2	2·1	2·9	3·3	**4·7**	4·3	1·9	1·2	0·6	23·6

PART IV

EUROPE (EXCLUDING RUSSIA)

CHAPTER XXVII

GENERAL FEATURES

EUROPE is essentially a peninsula of Asia, wide in the east, narrowing towards the west. On the north of the main peninsula which includes Russia and central Europe are Scandinavia and Jutland, which may be considered as secondary peninsulas, and the island group of Britain; similarly Iberia, Italy, and Greece are secondary peninsulas on the south. From the other point of view we note how the seas work their way far into the land, dispensing marine influences widely. On the north the North Sea and the Baltic are continued by the Gulfs of Bothnia and Finland while the White Sea extends south-west from the Arctic as if to make a continuous waterway to the Gulf of Finland over the great lakes of north-west Russia. In the Mediterranean Sea with its annexes the Adriatic, the Aegean, the Black Sea, and the Caspian, south Europe has an equally valuable series of enclosed seas to ameliorate its climate. The seas are not only extensive, but also remarkably warm for the latitude, since the waters of the Gulf Stream are driven across the Atlantic by the prevailing westerlies, and are still so warm when they reach Europe that the winters are remarkably mild.

The absence of a mountain-range along the west coast is another fact to which Europe owes great climatic advantages. Such a barrier exists in North America with the result that the mountains near the ocean receive from the westerlies a superfluity of rain of which man cannot make full use while the country to leeward suffers both from aridity and extremes of temperature. In Europe the major lines of relief, the Pyrenees, the Alps, the Carpathians, and the Caucasus, have a west–east trend, and they accentuate the abrupt transition from the Central European climate to the Mediterranean. There are, it is true, isolated groups of mountains facing the westerlies on the stormy seaboards of the British Isles and Norway, but in

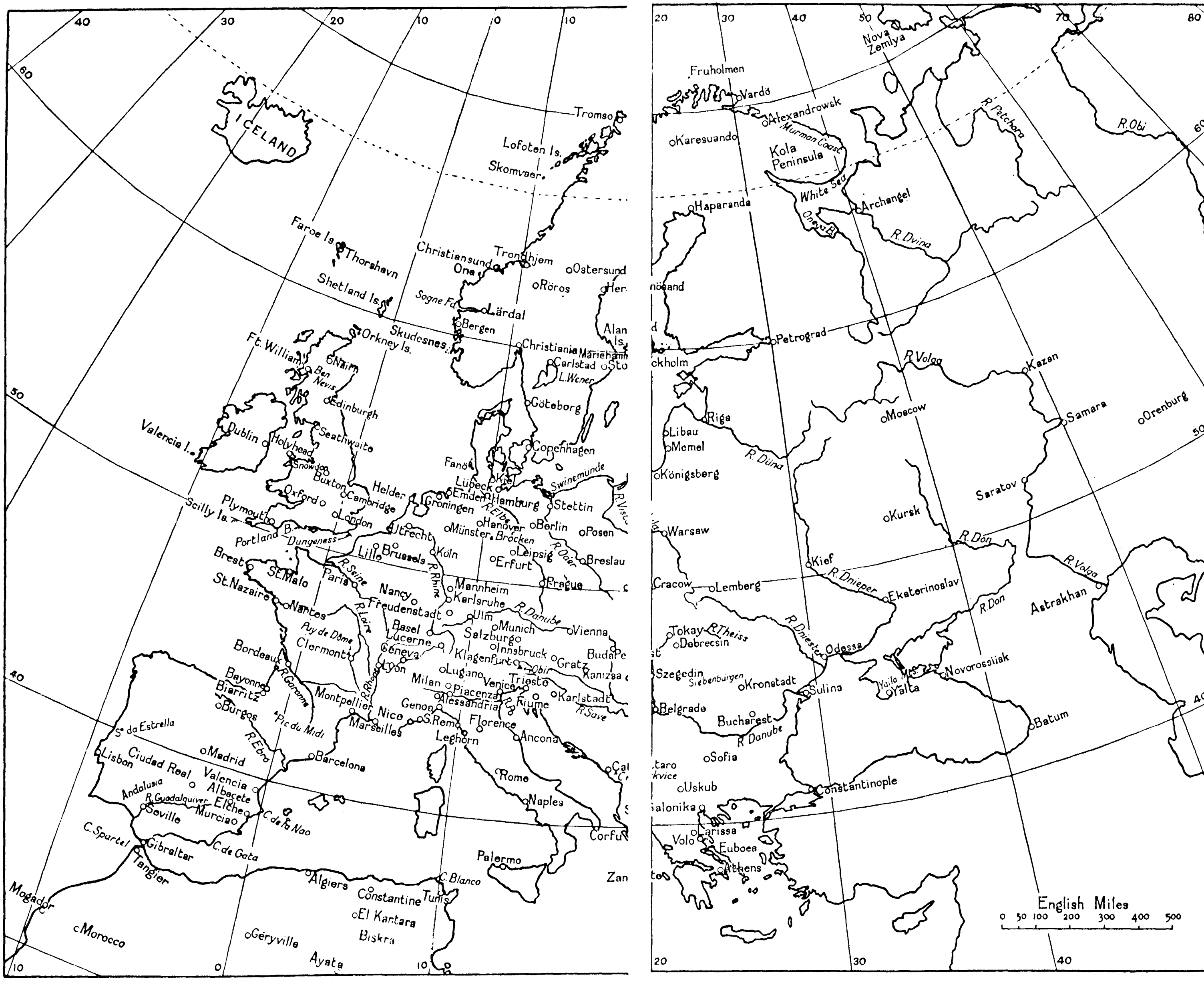


FIG. 93. Key map, showing the position of places mentioned in the text. See also Figs. 105 and 114.

spite of the large local increase in precipitation, they are not high and continuous enough to cause a serious deficiency of rainfall, or very extreme temperatures, in their lee. As a result it is exceptional to find sharp divides of climate in going from west to east; the transition is gradual from the oceanic seaboard to the continental east, and most boundaries are arbitrary.

The ubiquity and warmth of the sea, then, and the trend of the main feature lines give Europe a remarkably favourable climate, with very mild winters, warm but not too hot summers, very small range of temperature for the latitude, and abundant and well-distributed rainfall. In proportion to its size, Europe has a larger area with a climate which has proved itself suitable for the highest human development than any other continent, and even if Russia is included, it has only one small tract of arid desert, north of the Caspian Sea; the cold tundra fringe in the north is but narrow. Many useful crops flourish in higher latitudes in Europe than elsewhere. Of the ordinary products of temperate latitudes, barley is profitably grown beyond 70° N. in Norway, and rye almost as far north in Sweden. Wheat and the vine have their farthest poleward range. Subtropical fruits find unusually favourable conditions in the Mediterranean lands; the orange and the lemon grow there even beyond lat. 44° N., and groves of date-palms at Elche in south-east Spain. Nowhere else do these fruits ripen so far from the equator.

Pressure and Winds

The main air-streams are controlled by three great pressure-systems, the Icelandic low pressures, the Azores anticyclone, and the alternating high and low pressures, of winter and summer respectively, over Asia (Figs. 41 and 42).

In Chapter II the tendency to low atmospheric pressures round the globe about lat. 60° N. and S. was mentioned. The Icelandic low pressures and the corresponding Aleutian system of the North Pacific are the cores of lowest pressure over the warm oceans. They are specially deep and extensive in winter, when the difference in temperature between land and sea is largest, and the air is collected in extensive anticyclones over the cold continents. In the low-pressure systems cold dry polar

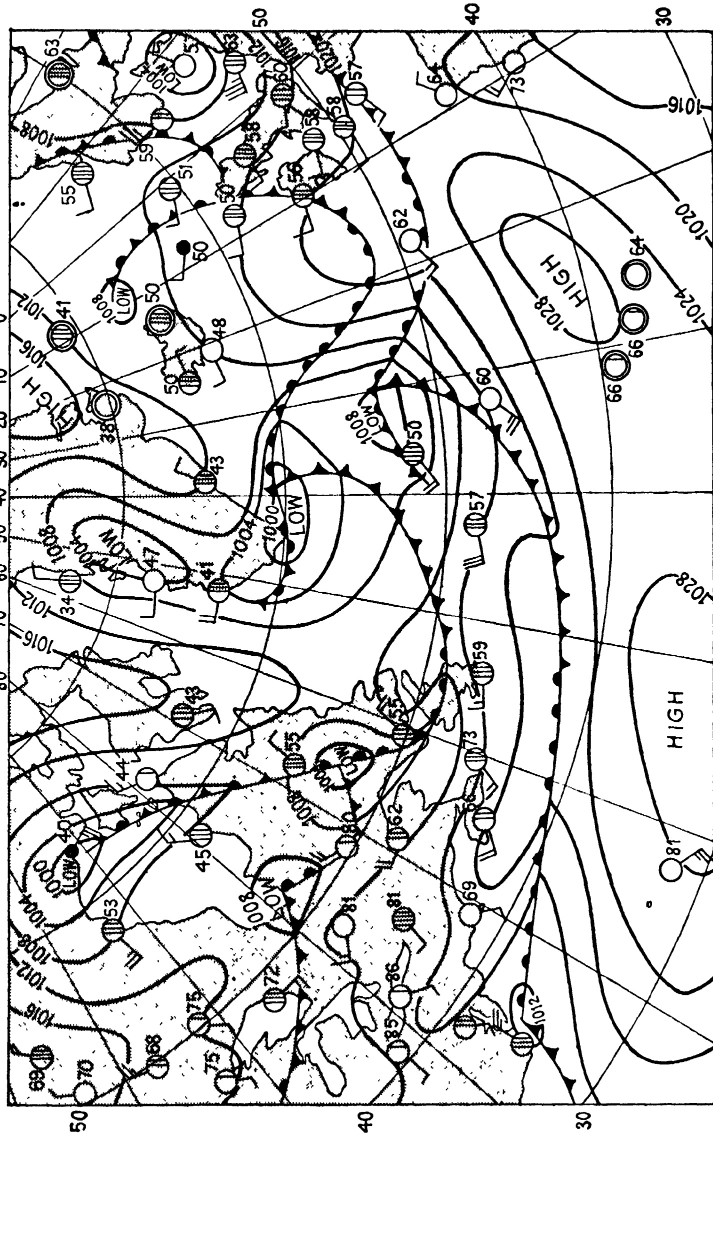


FIG. 94. Synoptic chart, North Atlantic, 7 Aug. 1947.

air from the anticyclones of Greenland, the Arctic, and the north of Eurasia and North America, meets warm tropical air moving north-east from the sub-tropics, and their interaction gives rise to the many depressions of these tracts, with their cloudy skies, frequent rain, and sudden changes of wind, temperature, and weather (Fig. 94). In the North Atlantic the normal belt of contact of the contrasted air-masses is the Atlantic polar front between the south-east of the U.S.A. and the English Channel (Figs. 4 and 5), and depressions originating in it tend to move off to the north-east, but with very irregular tracks and speeds. They are usually deepest south of Iceland, where consequently the mean pressure is lowest. A tongue of low pressure extends from here north-east beyond the north of Norway, the significance of which will be pointed out later; near its axis is the Arctic front, another belt of cyclogenesis. The depressions are the immediate cause of most of the storms of wind and rain in north and central Europe. The seas north-west of Europe, stormy at all times, are in winter one of the wildest regions on the earth.

In summer low pressures still persist over the Icelandic region, but less intense and with weaker gradients than in winter, and the travelling depressions are fewer and less vigorous.

The anticyclone in the neighbourhood of the Azores belongs to the sub-tropical high pressures. Pressure is highest in summer, and the centre of the system is then farthest north, about lat. 35°. It appears on the maps as a large anticyclonic system, not only on the Atlantic but extending far over west and central Europe and the west of the Mediterranean Sea. Its intensity in summer is due to the fact that the large continents are then hot, and their normal sub-tropical high pressures are replaced by the low pressures which give rise to the summer monsoon. The air collects over the cooler oceans, where, consequently, extensive anticyclones build up.

In winter the Azores high pressures are much less prominent and indeed they appear not as a fully developed anticyclone but merely as a band of high pressure, crossing the Atlantic about lat. 30° N. and connecting the anticyclones of Asia and North America. The line joining the middle of the Atlantic and the Asiatic high pressures passes over the Mediterranean

Sea. But that sea is warm and the air over it moist, and therefore conducive to low pressure atmospherics. The result is interesting. The high-pressure 'bridge' connecting the Atlantic and Asia divides, one branch following the axis of Europe, the other covering North Africa, and the Mediterranean region between them forms a 'lake' of low pressure (Fig. 7b, p. 33). The Black Sea and the Caspian for the same reason have lower pressure than the surrounding lands. The lowest mean pressures on the Mediterranean are less than 1,015 mb. (30·0 in.), over the Black Sea about 1,019 mb. (30·1), and over the Caspian less than 1,023 mb. (30·2 in.); pressures thus increase towards the Asiatic anticyclone. West-central Europe, therefore, is a region of high pressure in both summer and winter, but the Mediterranean Sea has high pressures in summer and low pressures in winter. Just as the Icelandic low-pressure system is not, strictly speaking, permanent, so the North Atlantic anticyclone is liable to considerable variations of intensity and position, and may even be replaced by low pressures.

The pressure conditions in Asia, the third of the great controls of the climate of Europe, have already been described in Part III. In winter the high pressures are continued west over south Russia, Romania, the Alps, south-central France, and the Iberian Peninsula. In summer Asia is a region of low pressure, an extension from which covers most of the north of Africa; but a tongue of high pressure projects from the Azores anticyclone over central Europe towards Siberia; the gradients are less steep than in winter and the axis is farther north, from the Bay of Biscay over south Germany to central Russia. This high-pressure ridge has been called the barometric backbone of Europe, and it is of fundamental importance in separating the north European climate, with its moist westerlies and cloudy skies, from the sunny Mediterranean.

The whole of Europe is subject to varying pressure-gradients and variable winds which bring air-masses of different character from widely different sources; the notoriously changeable weather, changeable in all its elements, results from this succession of air-masses. In 1947 Great Britain, which lies full in the westerlies, had easterly winds for 31 days, 22 Jan. to

22 Feb., without intermission. In north-west and north Europe, and also in most of Central Europe, the prevailing winds are from the west ('variable westerlies'), SW. in winter, NW. and W. in summer. They are controlled by the Azores high-pressure and the Iceland low-pressure systems. In winter the dominant control is the latter, which extends far south, but its axis is well to the north-west of Europe so that north Europe is swept by south-westerlies. In summer the Azores system spread north, and the low pressures over south Asia exert some control, stronger towards the east, so that the prevailing winds are north-westerly. These winds, blowing more directly into the continent, have been described as the summer monsoon of Europe. The strong westerlies of winter coming from the warm ocean, which is then a more potent source of heat than the direct rays of the sun, give the mild, moist, cloudy climate of west and north Europe. The extension of the Icelandic low pressures to the north-east carries warm oceanic conditions far over Scandinavia and north Russia.

The strength and constancy of the westerlies diminish towards the high-pressure axis of the continent, where they are often interrupted, notably in the Alps, by almost calm spells in winter under the domination of extensive anticyclones, which are much more frequent here than in the north-west, and give cold dry weather; in summer the prevailing winds are NW. controlled by the low pressures of south Asia. In south-east Europe the winds are NW. on the west shores of the Black Sea and NE. in the steppes of south-east Russia, the main control here also being the low pressures of Asia.

The European countries on the Mediterranean have the high pressures of the 'barometric backbone' on their north throughout the year and consequently the winds are northerly, NE., N., or NW. according to the lie of land and sea. In summer they are strong and constant, but in winter the frequent depressions in the Mediterranean give variable winds and rainy weather. The north coast of Africa being south of these depressions has prevailing westerly winds in winter, but strong northerlies in summer. The circulation over the Mediterranean region is described in Chapter XXX. The local relief and the trend of a coastline may give so strong a set to

the winds as to mask the general direction; Vienna has a marked preponderance of winds from west and south-east, Toulouse from north-west and south-east, Gibraltar from east and west. In general the winds are much stronger in the winter half-year, in most areas in winter and early spring, than in summer.

The mean wind directions at some representative stations in north-west and central Europe are given below, in Mediterranean Europe on page 351:

WIND DIRECTIONS, MEAN PERCENTAGE FREQUENCIES

January

	N.	*NE.*	*E.*	*SE.*	*S.*	*SW.*	*W.*	*NW.*	*Calm*
North-west Europe									
Valentia . . .	6	6	10	13	21	16	12	7	9
Lerwick . . .	12	4	3	14	17	14	28	8	0
Emden . . .	4	7	14	11	7	32	16	6	3
Köln . . .	1	4	4	38	5	15	20	13	0
Central Europe									
Frankfurt a/M. . .	9	15	10	4	7	37	8	3	7
Munich . . .	2	12	10	3	3	28	14	5	23
Berlin . . .	3	4	13	13	11	18	23	10	5
Breslau (Wroclaw) .	4	4	8	19	11	15	21	15	3
Koslin . . .	5	4	4	20	14	17	16	9	11
Vienna . . .	3	1	7	14	2	3	30	10	30
Budapest . . .	11	9	7	10	7	6	6	23	21
Szeged . . .	14	9	9	12	15	9	12	12	8
Belgrade (Beograd) .	5	2	10	21	4	3	12	11	32

July

	N.	*NE.*	*E.*	*SE.*	*S.*	*SW.*	*W.*	*NW.*	*Calm*
North-west Europe									
Valentia . . .	11	3	2	6	15	16	16	17	14
Lerwick . . .	15	15	6	11	10	9	17	12	5
Emden . . .	13	8	7	6	4	21	18	19	4
Köln . . .	2	4	3	21	5	18	25	22	0
Central Europe									
Frankfurt a/M. . .	13	13	6	3	6	30	15	8	6
Munich . . .	3	10	7	4	3	23	20	11	19
Berlin . . .	6	4	6	7	6	13	29	21	8
Breslau (Wroclaw) .	7	5	6	11	8	10	22	27	4
Koslin . . .	15	6	3	9	10	13	15	20	9
Vienna . . .	4	2	4	8	3	6	41	7	25
Budapest . . .	8	5	4	3	4	7	10	38	21
Szeged . . .	14	7	4	6	14	11	19	18	7
Belgrade (Beograd) .	5	3	3	8	3	4	20	16	38

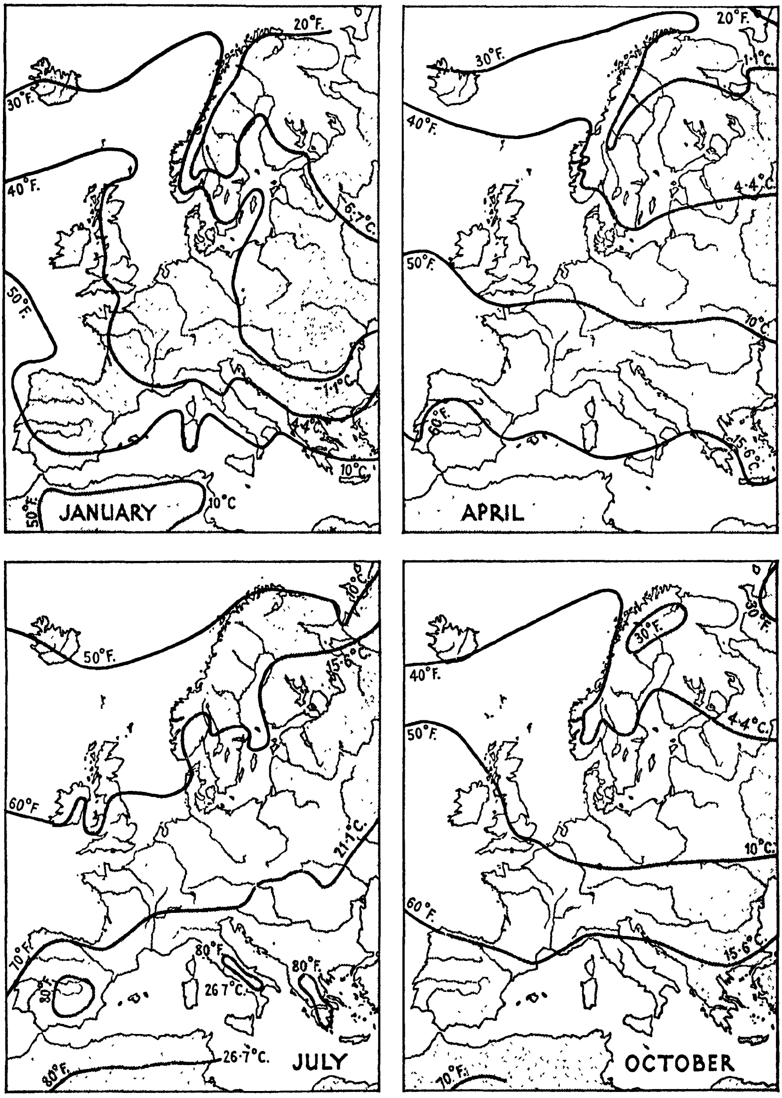


FIG. 95. Mean isotherms.

TEMPERATURE

No account is given here of the climatic elements of the continent as a whole, except pressure and winds, for they will be more conveniently described in the sections devoted to the separate regions, but it is convenient to glance at the general distribution of temperature, which presents many features of interest. Its most notable characteristic is equability. Along most of the west coast the range between the mean temperatures of the warmest and coldest months is less than 20°, a remarkably small figure for the latitude (Fig. 1). The range increases eastward, but in almost all Europe, excluding Russia, it is below 40°, and only in central Russia reaches 50° which is average for these latitudes.

The summer isotherms (Fig. 95) have a normal course, generally from west to east, but bending poleward as they go farther inland. Very little of Europe has a mean temperature below 50° in July, and the barren tundra lands are of small extent. At the other extreme, very small areas have a July mean above 80°, the 80° isotherm enclosing only the Mediterranean peninsulas. Thus Europe is not enervated by excessive tropical heat in summer, and though in all the Mediterranean lands summer means are high, exceeding 70° in 3 months (4 in the south), the air is dry and the climate healthy.

The isotherms for January are remarkable for their strong tendency to run north–south. Thus the 40° isotherm after trending north-east over the ocean makes a sharp curve round the Shetland Islands, and comes due south along the west of Scotland, England, and France; in the south of France it bends eastward to the head of the Adriatic Sea, turns south-east again over the Balkan Peninsula to the Aegean Sea near Salonica, and then north-east to the Black Sea. In the Shetlands it is 20° of latitude north of its southernmost position in the Aegean. Equally anomalous is the course of the 30° isotherm from Iceland north-east to beyond lat. 70° N., thence south-west along the Norwegian coast, and south through Jutland and Central Europe to the Danube, where it swings to the north-east. There is a difference of almost 30° of latitude, 2,000 miles, between its extreme north and south points.

Two main factors cause the north–south trend. The first

is that the middle of the European peninsula is cold, like all lands in middle and high latitudes at this season; the second, that the north, and especially the north-west, of Europe is abnormally warm thanks to the warm North Atlantic Ocean from which the prevailing winds blow. The air over the ocean west of Norway is more than 40° warmer than the average for the latitude, the greatest anomaly (see p. 16) of temperature on the globe (Fig. 96). This in turn is a result of the shape of the Atlantic basin, for, thanks to the fortunate accident that

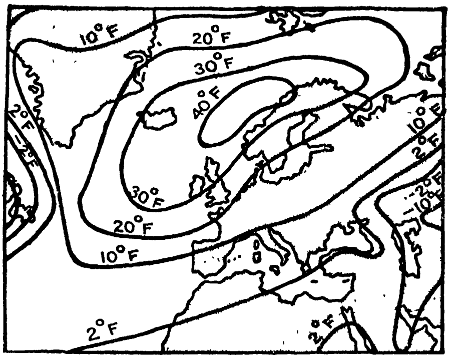


Fig. 96. Mean anomaly of air temperature, January.

the north-east of Brazil projects into the ocean a few degrees south of the equator, not only the North Equatorial Current, but also about half of the South Equatorial Current, are turned into the North Atlantic. In consequence the Gulf Stream and Antilles Current are specially voluminous, and the warm water is wafted on towards Europe by the prevailing westerlies, the wide opening between Europe and Iceland giving free passage north round Norway and along the Russian coast. Those northern seas are never frozen, in striking contrast to the waters north of America. Thus the usual advantages derived in middle and high latitudes in winter from oceanic winds are magnified, and the temperatures on the Norwegian coast are appreciably higher than on the west coast of North America in the same latitude.

The coldest winters are in the north-east of Russia with a temperature below 0°, the warmest in the south of the Mediterranean peninsulas marked off by the 50° isotherm, a line which migrates to the extreme north of Russia in July.

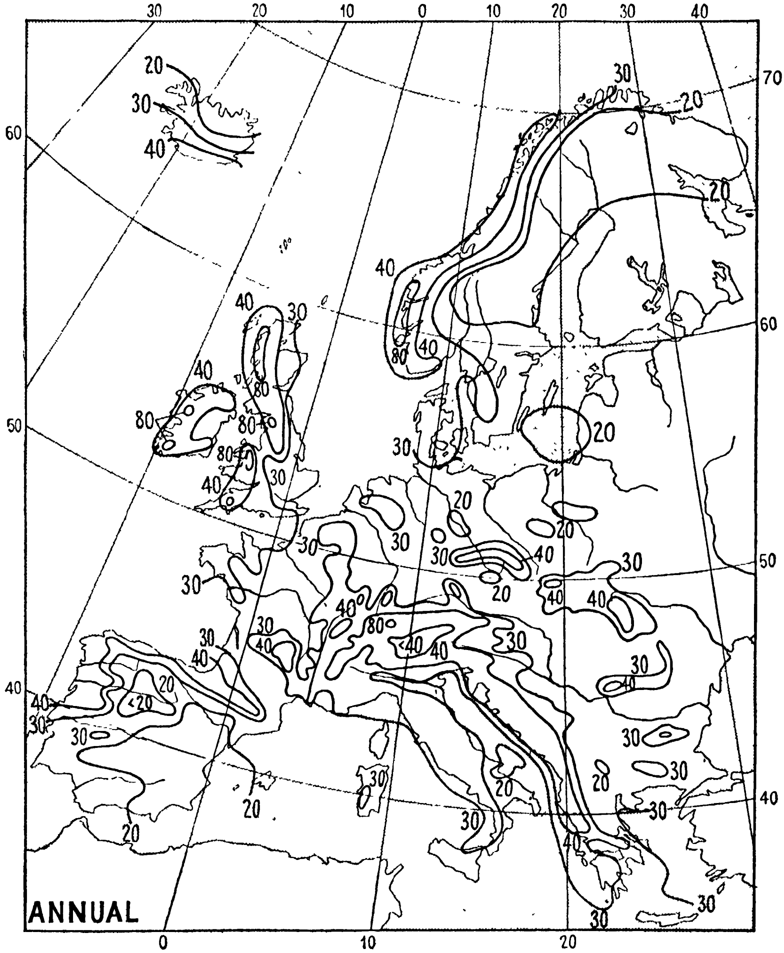


FIG. 97. Mean annual precipitation (in.).
Continental Europe based on B. J. Birkeland, N. J. Föyn, and E. Alt.

The south-west of the British Isles has a January mean almost as high as the French and Italian Rivieras. In most of west and north-west Europe, and on the Mediterranean coasts, no month has a mean below 32°; in the west of Germany the mean is below 32° for 1 month, in the east of Germany for 3 months.

If the isotherms of 32° for January and 70° for July are drawn on one map they divide Europe into four thermal

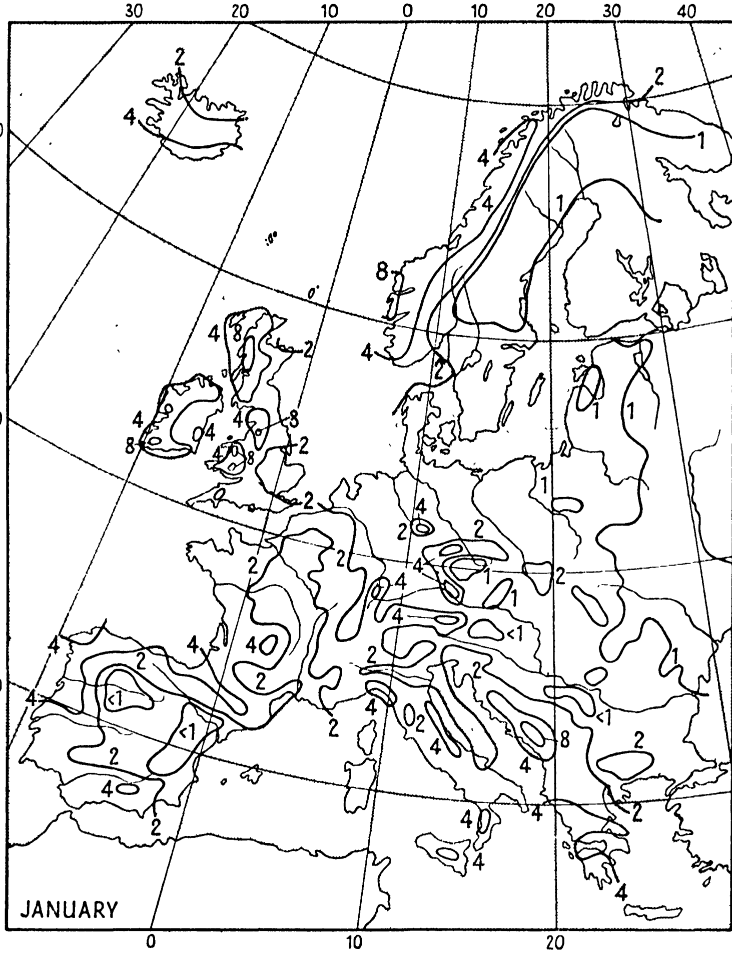


FIG. 98*a*. Mean monthly precipitation (in.).
Continental Europe based on B. J. Birkeland, N. J. Föyn, and E. Alt.

provinces, which have mean temperatures above or below 32° in January, and above or below 70° in July, respectively: (1) the north-west, with mild winters and cool summers, (2) the north-east, with cold winters and cool summers, (3) the south-west with mild winters and hot summers, (4) the south-east, with cold winters and hot summers.

The range of temperature (Fig. 1, p. 14) increases inland, and

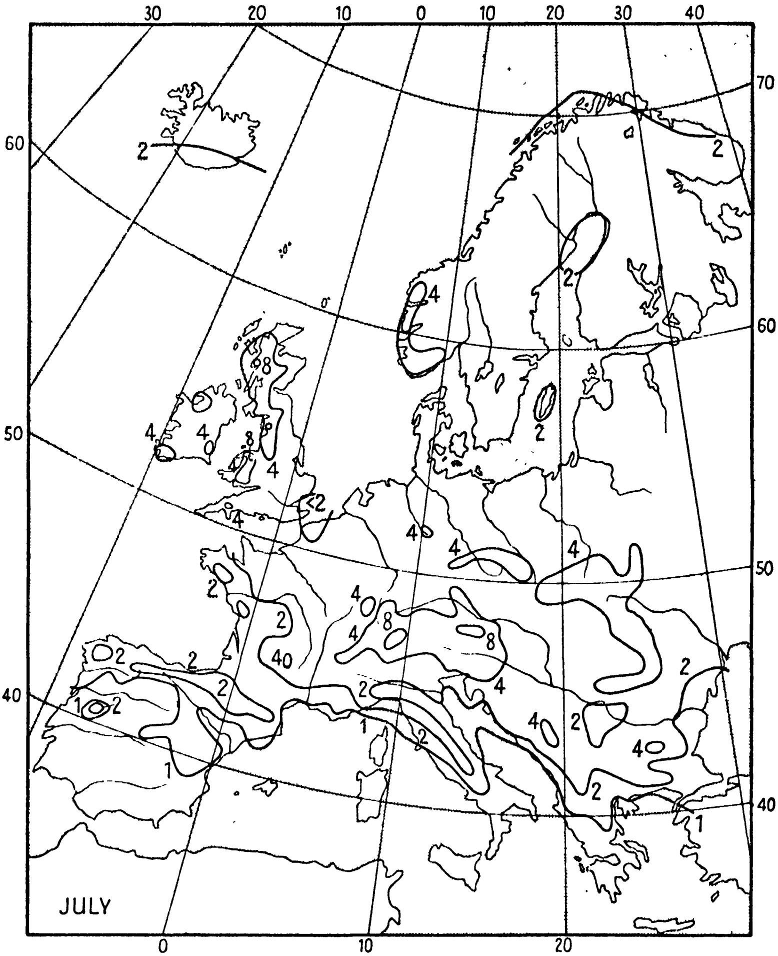


FIG. 98*b*. Mean monthly precipitation (in.).
Continental Europe based on B. J. Birkeland, N. J. Föyn, and E. Alt.

especially towards the east, owing to the colder winters and, in a less degree, the hotter summers:

		Mean Temperature, °F.		
	Altitude in feet	*Warmest month*	*Coldest month*	*Range*
Nantes	131	65	40	25
Basel	1,040	65	31	34
Vienna	663	67	28	39
Debrecen	423	70	28	42

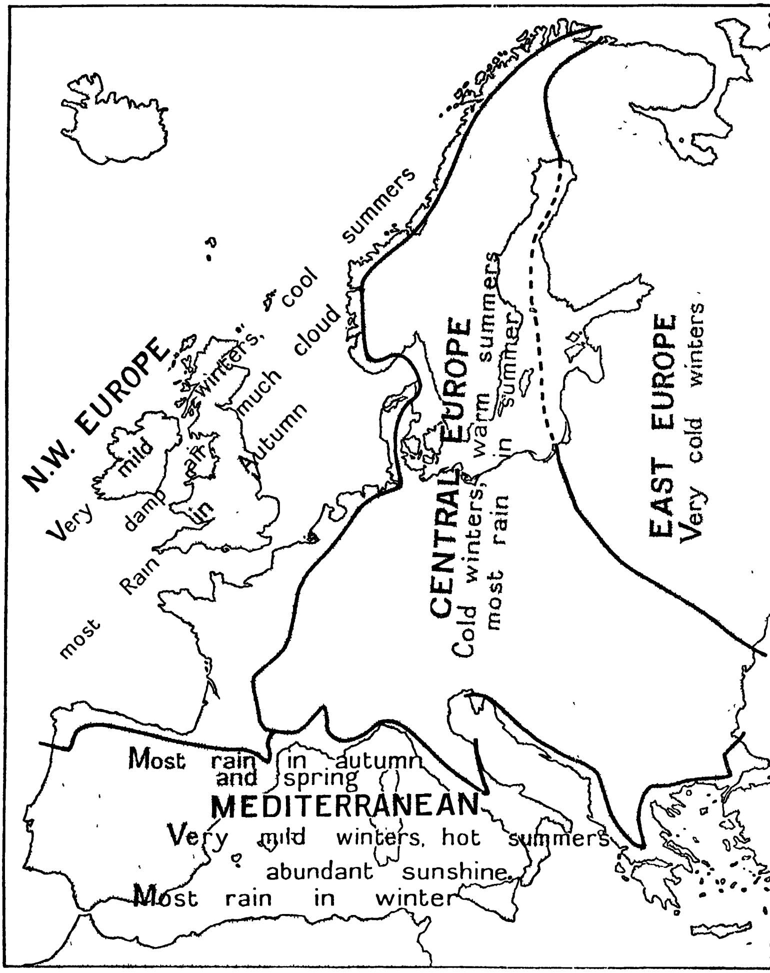


FIG. 99. Major climatic regions.

There will be frequent occasion in later chapters to refer to the general principle that the winters get colder, and the range of temperature larger, towards the east.

Figs. 97 and 98 show the distribution of precipitation.

The continent may be divided into four major climatic regions (Fig. 99). East Europe has been described already in Chapter XXVI, and descriptions of the others follow.

CHAPTER XXVIII
NORTH-WEST EUROPE

THE prevailing winds in winter are SW. in north-west Europe and also in north Russia owing to the extension of the Icelandic low-pressure system to the north-east. The strong winds and gales that rage round the shores have already been mentioned; their fury, added to the coolness of the summers, is unfavourable to tree growth, and the most exposed coasts, in the Orkneys and Färoe Islands for example, have no trees at all except in sheltered spots. In summer the Azores anticyclone extends farther to the north-east and the prevailing winds are W. to NW., much lighter than in winter, with few gales.

TEMPERATURE

Winter. In the last chapter one of the fundamental facts to which west Europe owes its open winters, the main peculiarity of its climate, was considered, the remarkable warmth of the surface water of the North Atlantic. It was seen that the mean air temperature in January on the ocean west of Norway is more than 40° above the average for the latitude. The excess decreases towards the east, and in central Russia the continental deficit begins. The mean temperature in January at Torshavn, Färoe Islands, is 38°, and severe frost is unknown; at Yakutsk, in the same latitude in eastern Siberia, the mean is −46°. Comparing the east and west shores of the Atlantic, we find a mean of 40° in January in the Orkney Islands, −6° at Hebron, Labrador, in the same latitude. The open sea on the north-west and most of the north of Europe is never frozen, but in very severe winters ice-floes large enough to be a menace to navigation may be drifted by the E. winds into the North Sea, and the inshore waters of even the south-east of England are frozen; such was the case in 1947. The harbours of north-west Germany are ice-bound about 1 day a year on the average, and navigation on the River Waal in Holland is interrupted by ice for 3 days.

The mean January temperature in north-west Europe is above (or only very little below) 32°; in the west of the British

Isles and France it exceeds 40°, and in Spain, the warmest part of the continent, it reaches 50°. The 32° isotherm for January skirts the coasts of Norway and Jutland, its abnormal course showing that temperature decreases from west to east rather than from south to north; the south-west of Ireland has the same mean as Nice and Rome. It becomes

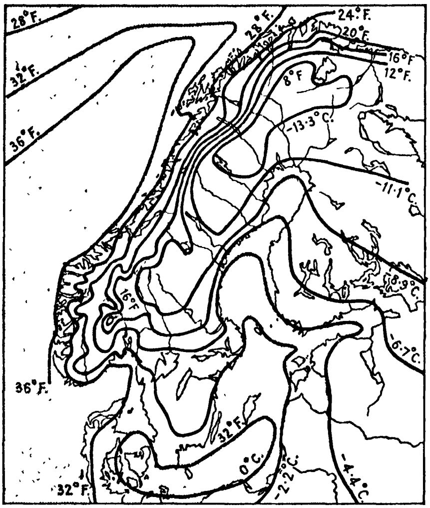


FIG. 100. Mean isotherms, January (after Graarud and Irgens, and Wallén).

rapidly colder towards the east; at Brest the January mean is 43°, at Paris 37°, so that in a distance of 310 miles from the coast the mean falls 6°; Paris is colder than Torshavn 850 miles nearer the pole. The west coast of the British Isles is appreciably warmer than the interior and the east coast, the January mean at Valentia being 45°, at London 41°. Similarly in Norway (Fig. 100), the heads of the longest fiords are as much as 10° colder than the open coasts, and their farthest recesses are often frozen over for some time in winter, but on the open coast ice is unknown even beyond the Arctic Circle. The January mean is 34° at Bergen, 24° at Oslo, which has comparatively severe winters with a mean below 32° for 4 months, being at the head of a fiord which runs far into the land, and in lee of the land-mass of Norway. Katabatic winds descend from the highlands when they are covered by

a cold anticyclone in winter, and fill the valleys of all Scandinavia, not only the west, with very cold air ('sno' locally); they may attain considerable velocities, especially in the fiords, in contrast to the usual feeble winds of winter in the interior. Kristiansund on the open west coast of Norway is warmer than Hamburg, about 700 miles farther south but some distance up the estuary of the Elbe.

No month of the year has a mean temperature below 32° except in the north of Norway; there the cold period rapidly lengthens towards the north, and inside the Arctic Circle 4 months have means below, but only a little below, freezing-point. Above 2,000 feet the climate is more rigorous, and the highest summits even in the British Isles have at least 1 month with a mean below 32°.

To consider the lowest temperatures that occur, on the west coast of Spain and Portugal frost even at night is very exceptional, and on the extreme west coasts of France and the British Isles frost is rare. At Paris frost must be expected on half the nights in the 3 winter months. In the neighbourhood of London the thermometer remains above freezing-point on January nights rather more often than it falls below it, and the temperature is seldom below 15°. On the coast of Norway frost is more frequent, but is very rarely severe except in the north. The extreme records are:

	Abs. min.	*Abs. max.*
Paris	−11°	105°
Greenwich (London) . .	4°	100°
Valentia	20°	81°
Scilly Isles (St. Mary's) . .	25°	82°
Ben Nevis (4,406 feet) . .	1°	66°
Oslo	−2°	95°
Fanaraken[1] (Jotunheim, 6,765 feet)	−26°	62°
Röros	−60°	—

[1] Data quoted by Manley, G.

To sum up, the winters of north-west Europe near sea-level are 'open', mild and windy, cloudy, damp and rainy—conditions brought from the windward ocean. Frost occurs, but is neither severe nor continuous in an average season; snow is most frequent in late winter and early spring, but is rarely a serious obstacle on the low ground (see p. 321). The weather is most open in the south, where mild years may pass almost

without frost; the north is much more stormy, and most winters have spells of some weeks of frost, more or less severe, brought by air-masses which originate in east Europe or Siberia. The winter of 1947 was exceptionally severe; most of Great Britain was under deep snow from 27 January to 13 March, with drifts to a depth of over 15 feet for many weeks on high ground. The mild winters of the south-west coasts of the British Isles and the west of France find expression in the vegetation. The strawberry-tree (*arbutus*) flourishes in the woods of Killarney, myrtle, fuchsia, and laurel grow well, and even the lemon-tree will live, given shelter, in south Devon, recalling the flora of the Mediterranean lands. Cornwall and Devon contrast with the bleak east of Britain in the verdure of their winter landscape and their cultivation of early vegetables and flowers.

Summer. The summers are cool, cooler on the coasts than in the interior, for at this season the sea is a cooling agent in spite of the North Atlantic Drift. The mean temperature in July ranges from about 70° in Portugal to 50° in the north of Norway. The interior is warmer than the coasts, but not nearly so much warmer in summer as it is colder in winter, the July mean being only slightly higher at Paris than at Brest, and 4° higher at London than at Valentia. Some absolute maxima are given in the table above. Only the north of Scandinavia is liable to frost in every month of the year near sea-level; the midnight sun cannot ensure immunity. In most of north-west Europe the 3 summer months at least are always free from frost.

Autumn is warmer than spring, a common feature of a maritime climate; the mean temperature at Valentia in April is 47°, in October 52°.

PRECIPITATION (Figs. 97 and 98)

Rainfall is in general abundant, and in the mountains excessive, in all seasons except spring. Rain is frequent even on the plains, the number of rain-days ranging in the British Isles from 160 in the south-east to 240 in the north-west. The driest tracts are the Paris and Garonne basins, the Low Countries and north Germany, and the east of the British

Isles, with from 20 to 30 inches of rain a year. Even low hills have more than the plains, the Pyrenees, the Central Plateau of France, and the highlands of Brittany showing their influence very clearly on the rainfall map. Notably heavy is the rainfall of the rugged western seaboard of the British Isles, in south-west Ireland, the Highlands of Scotland, the Lake District, and the Welsh mountains. The last has the heaviest rainfall in north-west Europe, indeed one of the heaviest in the continent, and it takes a high place among the totals of the world; at Styehead Pass, Cumberland, the annual mean is 170 inches, and round Snowdon it exceeds 200 inches; in October 1909 Llyn Llydau, Snowdon, had 57 inches, and in January 1872 Styehead Pass had 50 inches. The decrease towards the east is extraordinarily rapid; Ben Nevis has 171 inches, Nairn, 70 miles to the east, only 25 inches. Similarly in Norway the western highlands have about 100 inches, Bergen 84 inches, but the head of Sogne Fjord, 100 miles from the open coast and well 'shadowed' by high land, only 30 inches. The long and deep valleys east of the watershed, notably the Österdal and the Gudbrandsdal, are prominent rain-shadows with totals below 20 inches, in places below 12, in striking contrast to the large totals in the west.

The large precipitation of the west is due to the mountains which rise in the course of the prevailing westerlies. The warm sea provides abundant vapour, which the frequent pressure-irregularities assist in condensing. Fortunately the mountain-barrier is neither so high nor so continuous that the lowlands beyond are in danger of drought in normal years, though a succession of dry months may cause considerable inconvenience; in Europe as elsewhere rainfall is variable, but excess is a more frequent cause of difficulty than deficit.

Precipitation shows no strongly marked periodicity, being adequate in all seasons, but in most of north-west Europe spring is the driest season, and autumn the wettest since cyclonic activity is then vigorous, and the sea is warmest relatively to the land. Torshavn, Färoe Is. (table on p. 320) has an oceanic régime; the winter half-year is rainiest with 63 per cent. of the year's total, and of the four seasons winter and autumn have most, summer and spring least; January

is the rainiest month, June the driest. These facts have evidently a close connexion with the intensity of cyclonic activity on the Atlantic. The west coasts of Norway, the British Isles, and France (Bergen, Valentia, and Brest), have much the same régime as Torshavn.

To leeward of the western seaboard a change appears, summer becoming rainier at the expense of winter. In the British Isles (Oxford, London, Edinburgh) spring is still the driest season as at Valentia, but winter has almost the same percentage of the year's total rainfall. The summer maximum is

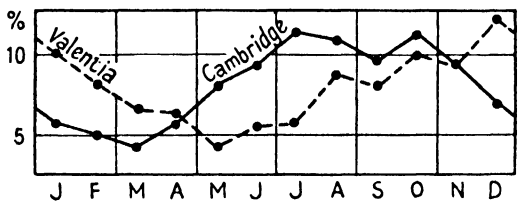


FIG. 101. Mean monthly precipitation, percentage of annual total.

highest in the east, the excess over spring at Edinburgh being equal to the excess of winter over spring in the west.

Over much of the east Midlands and the east coast of Great Britain as far north as Forfar, and the east of Ireland, the summer percentage is so much increased as to be the maximum of the year, but the autumn figure follows close behind; the summer excess is largest in East Anglia. North of Dundee autumn and winter are the rainiest seasons, the oceanic régime dominating the whole of north Scotland. The winter and summer half-years have similar totals, but it is interesting that the summer half-year is the rainier in much of the midlands and on the east coast except in the extreme north. Thus the east of the British Isles has continental affinities in its fundamentally oceanic régime.

The monthly precipitation has everywhere two maxima, one in autumn or winter, generally in October, the other in late summer, generally in August. Almost everywhere the autumn or winter maximum is the larger, and it results from the same causes that give a midwinter maximum on the ocean, cyclonic activity and the warmth of the sea (Valentia, Fig. 101). As autumn runs on into winter the land cools rapidly, and the

cold, together with the resulting tendency to high atmospheric pressure, prevents the rainfall increasing inland beyond the October figure in spite of the increasing storminess on the ocean. The late summer maximum is the larger only in a small part of the east of Great Britain (Cambridge, Fig. 101)

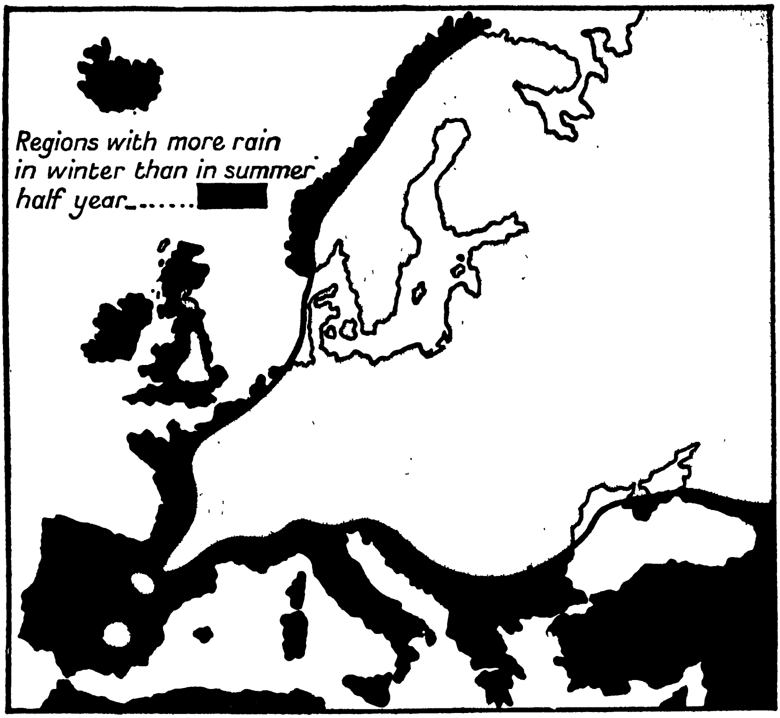


FIG. 102. Regions with most precipitation in winter and in summer half-year.

and of Ireland. It is a continental characteristic, which will be considered more fully in relation to precipitation in Central Europe where it is more prominent. September is a comparatively dry month between the rainier months of late summer and autumn.

Spring is the driest season everywhere in the British Isles, April and May the driest months. The sea is then coolest relatively to the land, so that the vapour-capacity of air from the sea is increased over the land and the air tends to become drier rather than to give rain. Moreover, there is a greater

tendency in spring than in other seasons for anticyclones to take up a position north of the British Isles, giving dry NE. and E. winds.

France shows a similar transition from the oceanic type of the west coast (Brest) with seasonal percentages much the same as in the west of Ireland, to the more continental régime of the interior with more precipitation in the summer than in the winter half-year. By far the greater part of the country conforms to this latter type, the oceanic régime being found only in a narrow coastal strip. In the north interior of France (Paris) summer is slightly rainier than autumn. In the centre (Clermont-Ferrand) and east (Lyon) summer is rainiest, with twice the precipitation of winter. But in the more continental as in the oceanic division, October is in most places the rainiest month (June at Clermont), and a secondary maximum occurs in early summer, June or July. Thus the interior of France shows clearly the transition from the oceanic type of the west with an autumn maximum and more precipitation in the winter than the summer half-year, to the continental type in which summer is the rainiest season and the summer half-year is rainier than the winter.

Seasonal Distribution of Precipitation in North-west Europe
(Percentages of the Yearly Total)

	Winter	*Spring*	*Summer*	*Autumn*	*Winter half-year*	*Summer half-year*
Torshavn	33	21	16	30	63	37
Bergen	29	18	21	32	58	42
Valentia	31	20	21	28	58	42
Oxford	24	21	28	27	51	49
London (Camden Sq.)	24	21	27	28	52	48
Edinburgh	22	20	31	27	48	52
Brest	29	19	19	33	59	41
Paris	20	23	29	28	46	54
Lyon	15	25	30	30	41	59
Clermont-Ferrand	16	26	32	26	38	62
Brussels	22	21	30	27	48	52
Emden	22	20	31	27	48	52
Hamburg	21	22	33	24	45	55

Brussels near the south coast of the North Sea has almost the same régime as Edinburgh; Emden and Hamburg are similar, but the summer maximum is more pronounced.

In north-west Europe, then, the oceanic type of rainfall

with its winter maximum is confined to a narrow coastal strip (Fig. 102). Immediately inland the winters become drier and the summers rainier. But, as already stated, the rainfall is sufficient in most seasons, without marked periodicity; even in the driest years serious drought is rare. With a warm ocean to windward the air is always damp, particularly in winter, and evaporation is slow, the mean annual evaporation from a water surface being only 16 inches at Camden Square, London. But the mean evaporation exceeds the precipitation in the months May to August:

MEAN MONTHLY EVAPORATION (IN.), CAMDEN SQ., LONDON

Jan. .	. 0·1	Apr. .	. 1·5	July .	. 3·0	Oct. .	. 0·6
Feb. .	. 0·3	May .	. 2·4	Aug. .	. 2·3	Nov. .	. 0·3
Mar. .	. 0·7	June .	. 2·9	Sept. .	. 1·4	Dec. .	. 0·1
		Year .	. 15·6				

Not lack of water as in the tropics, but the cold of winter, determines the resting-time for plant-life.

Snow. Most falls in winter and spring. In the lowlands of the British Isles it is rare enough to be a topic of conversation if it lies more than a few days; on the mountains, however, it often lies deep for long spells, the mean exceeding 100 days[1] in the highest Grampians and 50 days in the highest uplands of north England; Ben Nevis is snow-capped from mid-October till July. At Aberdeen the ground is snow-covered for 13 days in an average year, the longest period in the British Isles for a sea-level station; Oxford has 8 days, the south-west coasts of England less than 4. Paris has about 10 days, and north-west Germany, being liable to invasion by cold air-masses from the east, about 20 days (Aachen 21 days, Emden 24 days). In Norway the duration is least in the south-west, ranging from 10 days near the sea to 50 days on the inner fiords; it increases to 200–250 days on the high fjelde (290 days at Fanaraken, altitude 6,765 feet, in the Jotunheim[2]); in the north the littoral has 100–150 days, the interior about 200 days and the higher plateau more. Mountains have much longer periods than the neighbouring lowlands; an estimate for the central Pyrenees is 20 days at 2,000 feet, increasing to 170 at 6,000 feet and 240 at 8,000 feet.

[1] Manley, G., *Meteorological Magazine*, 1947. [2] Quoted by Manley, G.

The frequency of snow is indicated in the following table:

	Months with snow on more than half the days with precipitation	*Months with no appreciable snow*
Vardö	Oct.–June	July, Aug.
Trondheim . . .	Jan.–Mar.	June–Sept.
Aberdeen . . .	None	,,
Ben Nevis (4,406 ft.) .	Oct.–May	None
London	None	May–Nov.
Uccle (Brussels) . .	,,	May–Oct.
Paris	,,	May–Nov.

Cloud, Sunshine

The skies of north-west Europe are cloudy, indeed this is one of the very cloudy regions of the earth. In the south of England on the average of the year 7 tenths of the sky is covered; in September alone the cloud decreases to 6.

Sunshine is scanty, notably in the north of Scotland which projects into the most frequented cyclone tracks of the North Atlantic and sees the sun for only 1,200 hours in the year and for less than an hour a day in winter. On the south coast of England the mean annual total is 1,700 hours, but even this record represents a land of dull skies. Paris has 1,743 hours, Maastricht 1,521. The winters of the south-west of Ireland are as mild as those of Italy, but the sunshine records distinguish the regions, for Valentia has only 1,442 hours of sunshine in the year, 31 per cent., Rome 2,362 hours, 55 per cent., of the possible. North-west Europe is often cloudy and rainy and may not see the sun for days and even weeks together (in February 1947 no sunshine was registered in 21 consecutive days at Kew), but Rome is in the favoured Mediterranean region, where the rain may be heavy but is usually of short duration, and a day on which the sun does not shine is rare.

Visibility

Fog is frequent on the land in hollows during calm weather, especially on winter nights, and it can be very dense, discoloured, and persistent, in industrial districts. The coasts of north-west Europe, on the other hand, get fog in spring and summer; this is sea-fog, formed in tropical air-masses, drifting over the land but dissolving after a short advance.

CHAPTER XXIX
CENTRAL EUROPE

Central Europe is a transition region between the oceanic north-west and continental Russia. The prevailing winds over most of the area are westerly all the year, but are neither so constant nor so strong as in the north-west, and on many a winter day, while the shores of Britain are swept by gales bringing heavy rain and abnormal warmth from the western ocean, Germany is enjoying the cold, crisp, calm, air of an anticyclone, or, it may be, shivering in the grip of bitterly cold E. winds, often full of snow, sweeping across from Russia. The change is great indeed when mild westerlies from the ocean regain the upper hand over these harsh continental conditions. Temperature is more variable than in the British Isles, especially in spring; in March it has ranged between 73° and −2° at Berlin, between 72° and −7° at Breslau (Wroclaw).

A high-pressure belt, the 'wind-divide' of the continent, extends east–west over the Alps in winter, somewhat farther north in summer, so that north Switzerland and all Germany have prevailing W. winds, Hungary, Rumania, and the Balkan Peninsula N. and NW., dry and piercing in winter like those of the steppes of Russia.

Temperature

Winter. In Scandinavia the highland barrier which rises steeply from the west coast effects the change from oceanic to continental conditions within a few miles; the Norwegian coast has remarkably mild winters, and snow is only a temporary interruption of the humid and rainy conditions, but in the interior of the peninsula the cold is severe, and at Sveg, in a valley-bottom in central Sweden, the temperature has fallen to −56°.

The highlands of the south of Norway have a strong inversion of temperature in calm weather in winter (see second table on p. 324).

The east coast is warmer than the interior thanks to the Baltic Sea, but is much colder than the west coast. Below are given the mean temperatures at two series of stations; in the

first, across the south of the peninsula, Karlstad is warmer than might be expected from its position in the interior, an advantage derived from the proximity of the large lake Wener. In the second series, Karesuando, on the frontier of Sweden and Russia in lat. 68·5° N., is remarkably cold in comparison with Skomvaer to the south of the Lofoten Islands. Haparanda, on the north of the ice-covered Gulf of Bothnia, is only 5° warmer than Karesuando which is 1,050 feet higher:

	Altitude in feet	Mean Temperature *Coldest month*	Mean Temperature *Warmest month*	*Range*
Skudenaes	23	35	57	22
Oslo	82	24	63	39
Karlstad	174	26	63	37
Stockholm	144	26	62	36
Skomvaer	52	33	51	18
Karesuando	1,089	6	55	49
Haparanda	30	11	60	49

On the west coast south of Kristiansund no month has a mean temperature below 32°, but in the interior the mean is below 32° for 4 months or more.

Inversion of Temperature

	Alt. feet	*Mean temp., Jan.*	*Mean min. temp., year*	*Absolute min. temp.*
Röros (in bottom of upper Glommen valley)	2,067	13	−35	−60
Fanaraken (on snow-covered Jotunheim)	6,765	9	—	−26

The following table, compiled from data given by Wallén, shows the lengthening of the winter from south to north in Sweden, and illustrates the conditions in the high latitudes of Europe generally:

	Mean latest date with mean temp. below 32°	*Mean latest date with mean temp. above 32°*	*Mean number of days with mean temp. below 32°*
Malmö (Lund), 55·7° N.	4 Mar.	23 Dec.	71
Stockholm, 59·7° N.	27 Mar.	27 Nov.	120
Hernosand, 62·6° N.	7 Apr.	10 Nov.	148
Storlien, 63·3° N.	29 Apr.	24 Oct.	187
Haparanda, 65·8° N.	25 Apr.	23 Oct.	184
Karesuando, 68·5° N.	10 May	6 Oct.	216

In Russia and Finland, except on the Baltic coast, frost occasionally occurs north of lat. 60° N. even in July.

In Germany and Poland the winter cold strengthens rapidly towards the east; everywhere beyond the Elbe readings below zero are recorded in most winters, and at least 1 month has a mean temperature below 32°, in east Germany at least 3 months. The following table gives data for representative stations, all in the lowlands, the first series in the north, the second in the south of central Europe:

		January			*July*				
	Alt. feet	*Mean monthly temp.*	*Mean daily max.*	*Mean daily min.*	*Mean monthly temp.*	*Mean daily max.*	*Mean daily min.*	*Abs. min.*	*Abs. max.*
Münster .	207	34	39	29	63	73	54	−17	96
Berlin .	187	31	35	26	64	74	55	−15	96
Poznan .	190	29	—	—	66	—	—	1[1]	89[1]
Warsaw .	397	26	—	—	66	—	—	−4[1]	89[1]
Milan .	482	35	38	27	77	86	65	7	100
Vienna .	636	28	32	23	67	75	57	−8	100
Zagreb .	535	32	36	25	71	80	61	−4	94
Belgrade .	453	32	37	27	73	84	61	−14	107
Bucharest.	295	24	—	—	73	—	—	−3[1]	96[1]

[1] Mean annual extremes.

The rivers are frozen for a considerable period every winter; even the Saône in the east of France is closed to navigation for 15 days on the average. Eastward the duration increases rapidly; the Rhine is frozen for 13 days between the middle of December and the end of February at Köln, 15 days at Mainz (in the severe winter of 1829–30 no less than 220 miles out of the 270 between Mannheim and Holland were frozen, and in December 1879 170 miles); the Weser at Kassel for 20 days; the Elbe at Dresden for 31 days, at Hamburg for 35 days; the Oder at Frankfurt for 43. The Kiel Canal is closed on the average for 10 days (but more than 30 days in very cold winters). Even in the south of Germany long reaches of the Danube, despite its rapid current, are frozen, sometimes most of the distance between Regensburg and Passau; below Vienna the river often bears floating ice, but is not frozen over except near its mouth where it approaches the harsh winters of east Europe; here in a period of 51 years it remained open in only

10 winters; the date of freezing ranged from 7 December to 23 February and of break-up of the ice from 18 January to 30 March. The distributary at Sulina on the Black Sea is rarely frozen.

The rivers and the smaller lakes are frozen for about 130 days in the south of Sweden, 230 days in the north. Germany's North Sea coasts are rarely frozen, but ice-breakers are required to keep the harbour of Hamburg open. Her Baltic shores have more severe winters, and, though the open coast is rarely frozen, the harbours are ice-bound every year, Lübeck for 32 days, Swinemünde for 20, Stralsund for 27, Szczecin (Stettin) for 61, the inner harbour of Klaipeda (Memel) for 142; the inner recesses of the inlets may be frozen any time between the end of November and the beginning of March, but the ice does not usually extend far from shore. The Swedish coast may be blocked (Fig. 89, p. 275), but this is exceptional on the south and west. In the Gulf of Bothnia shipping is held up in an average year from November to May inclusive. In most winters there is enough drift ice in all parts of the Baltic to impede navigation, and the passages on the east of Denmark are more or less closed; in these narrow sounds the duration of the ice is more variable than in the open Baltic, and may exceed 4 months. The west coast of Denmark is always open. Ice is not unknown in Oslo Fjord, but it is never a serious obstacle.

Summer. Continentality makes the interior of the continent warmer than the seaboard, the isotherms curving poleward as they cross from west to east. Some representative data are given in the table above. In July the Arctic coast of Finland has a mean temperature just above 50° and the extreme south of Central Europe in the north of Italy and Greece 80°, sharing the heat of the adjacent Mediterranean lands. In Scandinavia Oslo, sheltered from the open sea behind the wide uplands of south Norway, has the warmest summers, and has recorded 95°. The limit of cultivation of the vine trends north with the isotherms to its farthest north in lat. 52° on the Elbe, east of which it returns south since the summers, though warmer, are too short to ripen grapes satisfactorily, and autumn is not so warm in east as in west Europe. Spring, however, is slightly warmer in the east, the maritime influence checking the rise of tempera-

ture in the west; the Baltic shores have notably raw cold springs. The very long summer days in the interior of the north of Sweden, where the mean sunshine record for June is 12 hours a day, sometimes have remarkably high temperatures; 99° has been recorded at Jokmok on the Arctic Circle. The hottest part of Central Europe in summer includes Hungary and Romania, the July mean being 72° at Szeged, 73° at Bucharest; these steppe lands are very hot on summer days.

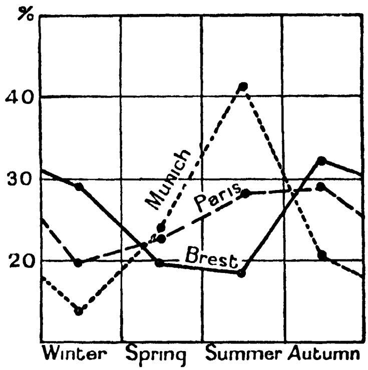


FIG. 103. Mean seasonal precipitation.

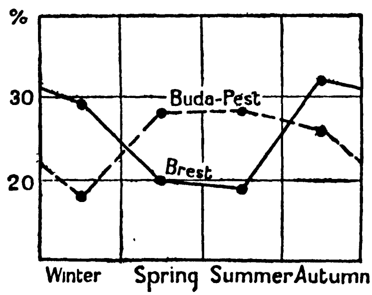


FIG. 104. Mean seasonal precipitation.

The land rises from the flats along the North Sea to the foot of the Alps, and this neutralizes the effect of the lower latitude in summer. Thus Berlin, altitude 187 feet, has a July mean of 64°, Munich, 1,739 feet, 63°. A special section (p. 333) is devoted to the modifications in the Alps.

PRECIPITATION

Central Europe north of the Alps is a well-watered land with mean annual precipitation 20 to 25 inches on most of the lowlands, 40 to 50 inches on the upper Hercynian highlands according to altitude and orientation. Thanks to the spread of precipitation over the year (summer has most, but no season is notably dry) and the low evaporation, these totals, though not large, are adequate for agriculture and the heavier rains in the hills feed reservoirs used for hydro-electric power and other purposes. The lands south of the Alps and Carpathians are less well provided, the totals falling to about 20 inches in the plains of the middle and lower Danube and about 15 inches near the Black Sea, and the rain is the less effective since a large part

of it falls in the hot summer months of strong evaporation. North Italy is better off, the Po plains having about 30 inches, together with excellent facilities for irrigation.

An instructive picture of the régimes is presented by 'sections' from west to east and from south to north (Figs. 103 and 104, and tables below). The first is from Brittany to Romania.

	Precipitation, percentage of yearly total							
	Winter	*Spring*	*Summer*	*Autumn*	*Winter Half-year*	*Summer Half-year*	*Months with most*	*Month with least*
Brest	29	*19*	20	**33**	59	41	Oct.	May
Paris	*20*	23	**28**	28	48	52	Oct., June	Jan.
Karlsruhe	*19*	23	**32**	26	44	56	June, Oct.	Feb.
Munich	*15*	24	**40**	21	32	68	July, June	Feb.
Salzburg	*14*	23	**42**	21	30	70	July	Jan.
Klagenfurt	*12*	23	**34**	30	37	63	Aug., June	Jan.
Budapest	*19*	27	**28**	26	44	56	June, May, Oct.	Feb.
Szeged	*19*	26	**31**	24	42	58	June, Oct.	Feb.
Bucharest	*19*	25	**34**	21	40	60	June, May	Feb.
Sulina	*19*	23	28	**30**	45	55	June, Sept.	Feb.

In Brittany most precipitation is in autumn and winter—an oceanic régime. At Paris the maximum is in summer, but autumn has almost the same percentage, and the summer half-year has more than the winter half; October is the rainiest month but June has a secondary maximum; this is the régime of most of France, but in the south-east the secondary maximum is in May. Entering Germany, at Karlsruhe we find a continental régime, with a pronounced summer maximum; the rainiest month is June, but the secondary maximum in October shows that the oceanic influence is not yet completely lost. Munich and Salzburg have a more accentuated continental régime, without a secondary maximum in October. In Austria and Hungary a new tendency appears, spring becoming more rainy at the expense of summer; in most of Hungary and Romania over a quarter of the precipitation is received in spring, much less in autumn; summer is the rainiest season, and May and June are the rainiest months. At Budapest the régime is almost the reverse of that of Brest.

The second section runs from the head of the Adriatic to the Baltic; Central Europe is bounded on the south by the Mediterranean region with rainy autumns and dry summers, represented by Rijeka (Fiume), which has most precipitation in October, least in July, and a secondary maximum in June:

	Precipitation, percentage of yearly total						*Months with most*	*Month with least*
	Winter	*Spring*	*Summer*	*Autumn*	*Winter Half-year*	*Summer Half-year*		
Rijeka (Fiume) .	*20*	23	*20*	**37**	54	46	Oct., June	July
Zagreb (Agram).	*17*	23	**30**	**30**	45	55	Oct., June	Jan.
Budapest . .	*19*	27	**28**	26	44	56	June, May, Oct.	Feb.
Prague . .	*13*	26	**38**	23	31	69	June	Feb.
Wroclaw (Breslau)	*18*	24	**37**	22	38	62	July	Feb.
Berlin . .	*22*	22	**33**	23	43	57	July	Feb.
Kiel . . .	22	*20*	**31**	27	48	52	July, Oct.	April

The Mediterranean régime dies out rapidly as the sea is left, and Karlovac (Karlstadt, Croatia) and Zagreb (Agram) have more rain in summer than in winter, but the Mediterranean influence can be traced to the north frontier of Hungary in the increase in October. The table below shows how October becomes relatively drier with distance from the Adriatic, and summer, particularly early summer, rainier.

At Budapest early summer is the rainiest season, the régime of the steppes of Hungary resembling that of south Russia (p. 278). Farther north the maximum is retarded; July is the rainiest month and spring becomes drier, but even on the

PERCENTAGE MONTHLY PRECIPITATION

	Distance in miles from Adriatic Sea	*January*	*February*	*March*	*April*	*May*	*June*	*July*	*August*	*September*	*October*	*November*	*December*
Rijeka (Fiume) .	0	6	*6*	8	9	8	8	*4*	6	11	**15**	11	8
Karlovac . .	55	5	*5*	7	8	9	**11**	*7*	9	10	**12**	10	7
Zagreb (Agram) .	80	5	*5*	6	8	10	**11**	*9*	10	9	**12**	9	6
Nagykanizsa. .	145	*4*	5	6	9	**11**	10	10	10	*9*	**11**	9	6
Budapest . .	265	6	*5*	7	9	11	**12**	8	*8*	8	9	8	8

Baltic coast (Kiel) the winter maximum of north-west Europe does not appear. In almost all Sweden the maximum comes still later, in August, with a very minor rise in October.

The two sections, then, illustrate that in much of France away from the coasts and in the south and west of Germany the rainiest month is June, and that the maximum is still earlier in Hungary and Romania, which resemble the steppes of south Russia. February is almost everywhere the driest month, and winter the driest season. In the interior of the continent autumn is drier than spring.

The winter minimum is the result of the high pressures over Central Europe due to the winter cold; the cushion of stable dense air tends to ward off the depressions which give so much rain to north-west Europe. But in summer pressure is lower, and depressions, though neither so numerous nor so deep as in winter, reach Central Europe more easily. The prevailing NW. winds bring damp maritime air, much warmer than the continental air of winter, and provide more precipitation for a given fall in temperature. The heating of the ground by the strong sunshine causes instability, and convection often results in heavy thunderstorms; in Hungary 61 per cent. of the rain in June falls on days with thunder. Instability is at a maximum in June, when the surface layers of the maritime polar air of early summer are being rapidly warmed and the higher layers are still cool and indeed little past their minimum temperature of the year; in high summer the instability is less, for though the surface air is warmer the upper air is more so. The precipitation of early summer is increased by shallow 'thermal' depressions for which the transition period with its weaker general barometric gradients is more favourable than high summer when the summer circulation is fully established. Thus in Central Europe, and particularly in the Danube plains, the summer rain is of a showery type, falling from cumulo-nimbus cloud with a tendency to thunder (which is about twice as frequent as in the south of England, being heard on 43 days at Munich, 26 at Vienna, only 14 at Kew).

Though summer is the rainiest season in Central Europe, yet, as in north-west Europe, the relative humidity is less than in winter, and evaporation more active, which makes the seasonal distribution of moisture more uniform for animal- and plant-

life than the monthly precipitation indicates. Summer, too, has least cloud, but most of Central, like north-west, Europe must be described as cloudy in all seasons. In central and south Germany the mean cloud is about 8 tenths in December, 6 in July. The Danube plains, middle and lower, have less, about 7 tenths in December, 4 tenths in July. The south-east has much more sunshine than the cloudy north:

MEAN SUNSHINE (HOURS)

	Month with most	*Month with least*	*Year*
Copenhagen	267 (May)	18 (Dec.)	1,598
Tartu (Dorpat)	281 (June)	19 ,,	1,682
Berlin	247 ,,	34 ,,	1,614
Berne	256 (July)	58 (Jan.)	1,781
Vienna	265 (July)	46 ,,	1,782
Sulina	338 (June)	67 ,,	2,246

It is only on crossing the Alps that we leave the region of gloomy skies and enter, suddenly, the bright and sunny Mediterranean world.

Snow. Much of the winter precipitation is snow, which is frequent though not usually of great depth. But on the highlands of south Norway it lies deep and crisp from November to April, and above 6,000 feet throughout the year. The depth and duration of the snow decrease towards the lower and drier east; the low ground is covered from November to February inclusive round Stockholm and from November to March in the middle of the peninsula in that latitude. In higher latitudes the snow lies longer, for 6 months at Haparanda, 8 at Riksgränsen, and all the year on the highlands of north Sweden above 3,500 feet. The whole of Finland except the coastal strip bears a white carpet from early November till late April. In South Sweden the average is only 1 month, and in Denmark the winter often passes without the ground being covered for any appreciable time.

In the east of France north of the Rhone the duration is estimated at 10 to 20 days (but over 40 on the Côte d'Or), and in Holland and Belgium at less than 10 days on the coast, rising to 20 in the east.

In Germany snow is frequent though generally of no great depth. The ground is covered in the north-west (lowlands) on the average for about 25 days between the middle of

December and the middle of March (Köln 23 days, Münster 27), in the east about 40 days (Berlin 37, Szczecin 47, Wroclaw 44). The highlands have far more, and their snow-cover exceeds 40 days in the west, 50 days in the east (about 80 days on the highest Ardennes, 100 on the upper Cevennes, 150 on the tops of the Jura and Vosges). In the south of Germany snow is most frequent in January, February, and March, and the low ground is white for about 20 days (20 days at Frankfurt, 17 at Ludwigshafen), the duration increasing rapidly with altitude, being 60 to 100 days at 2,000 feet (57 days at Munich, 1,730 feet; 107 days at Berchtesgaden, 2,000 feet; 167 days on the Feldberg, Black Forest, 4,150 feet). Snow is frequent in winter on the plains of Hungary and Yugoslavia, and the ground is covered for about 40 days in the north, 30 days in the south. The shores of the Black Sea are covered for 1 or 2 weeks in most years.

The relative frequencies of snow and rain are indicated by this table:

	Months with snow on more than half the days with precipitation	*Months with no appreciable snow*
Stockholm	Dec.–Mar.	May–Oct.
Groningen	None	Jan.–Dec.
Puy de Dome (summit)	Dec.–Apr.	June–Sept.
Strasbourg	None	Apr.–Nov.
Berlin	Jan.–Feb.	May–Oct.
Warsaw	Dec.–Mar.	,,
Berne	,,	,,
Davos	Oct.–Apr.	July–Oct.
Säntis (summit)	Sept.–June	None
Vienna	Dec.–Mar.	Apr.–Oct.
Belgrade	Jan.	,,
Bucharest	,,	,,

Visibility

In autumn and winter low cloud, mist, and fog, are frequent inland in calm weather, particularly on low marshy ground, forests, and lakes. Industrial districts, notably the Ruhr, are subject to industrial haze or fog in the nights and mornings, and it often persists all day. Anticyclones may give gloomy weather with unbroken palls of stratus and strato-cumulus cloud. In spring and summer the interior has little fog, but the coasts, of the Baltic in particular, are subject to sea-fog.

The Alps

Mountains make their own climates. The Alps offer a particularly tempting field for investigation, since they are the greatest ranges in Europe, and excellent series of meteorological observations are available. Furthermore the region is often dominated by anticyclonic conditions, under which some of the most interesting peculiarities of mountain climate occur. The Alps extend in a wide sweep of over 600 miles from the Mediterranean coast of the south-east of France to Vienna. For the first 100 miles they have Mediterranean climatic affinities, but beyond they belong to central Europe. The range is a formidable obstacle to air-masses approaching from either north or south, and modifies them both vertically and horizontally; its influence may be felt for some distance, as is sometimes the case when an air-mass from the north is deflected and a lee depression forms over the Gulf of Genoa and north Italy.

Temperature. The annual mean decreases about 1° F. in 330 feet of increase in altitude. But this value is derived from very diverse figures, and applies to few series of simultaneous readings. The actual gradient depends on the time of day, the season of the year, the state of the weather, and especially on the topography. In the Alpine region major topographical types are (i) wide open plains such as the Swiss Plateau, 1,200 to 2,500 feet above the sea, which belong climatically to the plains of Central Europe rather than to the Alps (e.g. Basel and Geneva), (ii) wide deep valleys and narrow steep-sided ravines between some of the highest ranges in Europe, with climatic peculiarities which vary according as they open to the north or the south, the east or the west (Altdorf, Klagenfurt), (iii) upland valleys (Andermatt, Davos), (iv) mountain-summits (Säntis). The mean temperature and precipitation of representative stations are given on pages 381 and 386.

In many places topography has more influence than altitude. Below are temperatures at Lucerne almost on the Swiss Plateau, the Rigi, an isolated summit overlooking Lucerne from 4,400 feet above, and Bevers in the bottom of the Upper Engadine, a deep trench between lofty ranges. Bevers has approximately the same altitude as the Rigi, but the topography is in complete contrast.

Mean Temperature

	Alt. feet	January: Mean of month	January: at 0730	January: at 1330	July: Mean of month	July: at 0730	July: at 1330	Range, July–Jan.
Lucerne .	1,634	31	29	35	65	60	71	34
Rigi .	5,863	24	23	26	50	49	53	26
Bevers .	5,610	14	10	24	53	49	62	39
Difference								
Lucerne–Rigi	–4,229	7	6	9	15	11	18	8
Rigi–Bevers	253	10	13	2	–3	0	–9	–13

The atmosphere is heated hardly at all by the passage of the direct rays of the sun, but almost entirely by conduction from the ground which is heated by those rays. Hence the warmest places are valley-bottoms where the air rests on concave slopes which provide the greatest area of contact. The summits and convex slopes of highlands, on the other hand, though strongly heated by the bright sunshine, have only small areas of contact with the air around them. The movement of the air is another factor; at the higher levels the wind is usually strong, and the air cannot be warmed so much during its short contact with the warm rocks as the calmer strata below. The nocturnal cooling of the air results from contact with the ground which loses its heat rapidly; the concave valleys are as effective in cooling the air at night as in warming it by day. Moreover, the coldest air tends to drain from all the slopes around and collect in the bottoms, where it forms stagnant 'lakes' with temperature sometimes lower than on the heights. Such inversions are most frequent in calm anticyclonic weather. It is true that owing to the clearer and less dense blanket of air the sun's rays at great elevations are powerful, and the mountain tops become hot by day; they also lose their heat very rapidly at night. But the other influences outweigh this in controlling the shade temperature of the air.

Valleys, then, are specially warm in comparison with the summits on summer days, and cold on winter nights, as is illustrated by the means given above for Lucerne and Rigi; the Rigi is 18° colder than Lucerne at 1330 in July, only 6° colder at 0730 in January. The Rigi and Bevers present a striking contrast. The two stations are at almost the same altitude, but in January the valley station is 13° colder than the summit in

the morning, in July 9° warmer during the heat of the day. The range of temperature is least on the Rigi, greatest at Bevers. The lowest reading ever recorded in Switzerland, −27°, was taken at Bevers. The Rigi can show nothing below −17°, and even on the Säntis, a summit 8,200 feet above the sea, the absolute minimum is only −25°. On the top of Mont Blanc −45° has been recorded. The mean winter temperature is, as a rule, higher well up the sides of a valley than in the bottom, and this is one of the reasons that many mountain villages are built at some height above the valley-floor. The Brünig Pass (altitude 3,315 feet) is somewhat warmer in winter than Meiringen (1,985 feet) below it in the Haslital.

It is especially in November, December, and the first half of January that the higher stations enjoy the greatest advantages, that is to say when the days are shortest. In that season a gloomy pall of fog often enshrouds the lowlands of the Swiss Plateau for a week together, and penetrates into the mountain-valleys to an altitude of about 2,500 feet. If we ascend we rise out of the damp, cold, dark, sunless winter and come out suddenly into a wonderland of sunshine and beauty. The landscape is full of light, the air is mild and dry and exceedingly bracing, and we enjoy to the full a warm climate only comparable with that of Alpine summits of more than 6,500 feet on clear calm summer days. The sudden change above the fog is astonishing, and in particular the transparency and dryness of the air, together with the bright light, are at first almost overpowering (MAURER).

Inversions are most notable in anticyclonic conditions:

	Alt. *feet*	Temperature at 0700 1881 *25 Dec.*	*26 Dec.*	*27 Dec.*
Altdorf	1,480	20	19	23
Rigi	5,863	13	27	35
St. Gotthard Pass	6,877	−2	24	30

On 25 December the weather was cyclonic and the wind strong, and the St. Gotthard was 22° colder than Altdorf. But next day an anticyclonic calm brought about an extraordinary change. The Rigi became 8° warmer than the valley station, the St. Gotthard 5° warmer; the temperature at the St. Gotthard rose 26° in 24 hours, and the inversion still continued on the 27th. In such calms the coldest air collects in the hollows; but the strong winds of depressions mix the strata, adiabatic

temperature changes are predominant, and the greatest altitudes are the coldest.

The winters are most severe in the valley-bottoms of the eastern Alps, which are shut off from western influences and are more subject to anticyclonic inversions. The basins of Klagenfurt and Graz have notable extremes; at Graz (altitude 1,129 feet) the mean temperature in January is 29°, in July 67°, and the mean annual extremes are 85° and 4°. The following series, computed by Hann and Conrad, illustrates the conditions at Klagenfurt, in the bottom of a wide enclosed basin, and stations at increasing heights on the mountains which enclose the basin:

	Alt. feet	*Mean temp. January*		*Alt. feet*	*Mean temp. January*
Klagenfurt	1,444	25	Lölling	2,756	28
Althofen	2,356	26	„ Berghaus	3,619	29
Hüttenberg	2,569	27	Stelzing	4,626	25

The means first increase up to about 3,600 feet, above which they fall. The following is an interesting example of the extreme cases of inversion which may occur; the Obir is a summit which looks down on Klagenfurt from the south-east, and the fortnight referred to was one of abnormally high atmospheric pressure with calm air over all central Europe, and unusually severe cold:

16–28 December 1879

	Alt. feet	*Mean temp.*	*Mean cloud (tenths of the sky covered)*
Klagenfurt	1,444	3	3
Obir	6,695	24	2

The poljes of the eastern and the Dinaric Alps collect similar lakes of cold air on calm winter nights. As a general rule the valley-bottoms are relatively coldest in the coldest winters, warmest in the mildest, since cold winters are the result of anticyclonic, mild open winters of cyclonic conditions.

Valleys with a wide opening allow the cold air to drain away, and they are not so cold as enclosed basins. Such valleys opening towards the north-west of the Alps are indeed abnormally warm in winter. Altdorf, in the deep Reuss valley just above the Lake of Lucerne, and Lucerne at the other end of the lake

on the Swiss Plateau at the same altitude, make an interesting comparison—

	Alt.	*Mean Temperature*		
	feet	*January*	*July*	*Range*
Altdorf	1,480	32	64	32
Lucerne	1,634	31	65	34

The monthly mean is a little higher at Altdorf in January (but lower in July) owing mainly to the warm föhn wind which it

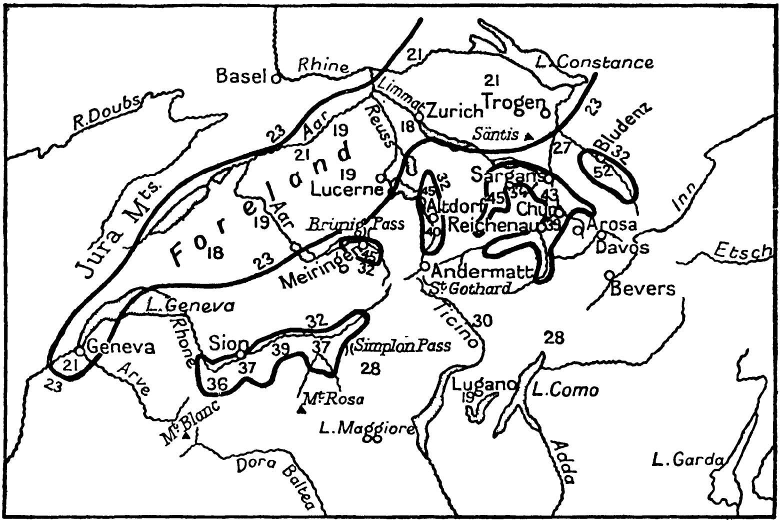


FIG. 105. Temperature in Switzerland during a föhn wind.

sometimes enjoys. This is a wind which has crossed the ranges on its journey from the south, and is heated and dried by compression as it descends the northern valleys, sometimes with gale force, to give remarkably large and sudden rises of temperature. It is well known in many Alpine valleys, the frequency and intensity depending on the topography. On Christmas morning 1870 Trogen, near St. Gallen, recorded a temperature of —1°, and the valley was full of cold, foggy, stagnant air. But a change set in about noon. A depression had appeared on the north of the Alps, and air was drawn towards it from the south, across the mountains. It blew as a föhn at Trogen, raising the temperature to 41°, a rise of 42° in 24 hours. In the Reuss valley föhn winds blow on an average 48 days a year, March, April, and May having most, with a very appreciable

effect in raising the mean temperature of the winter months. The pronounced föhn effect is lost when the wind passes beyond the narrow valleys (Fig. 105).

The upper Rhine, the Reuss, and the upper Aar are indeed climatic oases in winter thanks to their frequent föhn winds. The Rhone valley between Martigny and Sion is specially dry and warm, and the vegetation is reminiscent of subtropical types, but the very warm summers are chiefly responsible for this.

A föhn usually blows for 1 or 2 days, but sometimes as long as a week. The frequency is naturally very variable from year to year; no definition of 'föhn' is laid down, and observers differ somewhat in use of the term, but the average frequency may be indicated:

MEAN NUMBER OF DAYS WITH FÖHN

	Jan.	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*
Martigny .	3	3	5	**6**	4	1	*1*	1	3	5	**6**	*2*	39
Altdorf . .	4	4	6	**6**	6	3	2	*2*	3	**5**	4	*4*	48
Innsbruck .	*3*	3	6	**6**	5	2	2	*1*	2	**5**	4	3	43

In strong contrast to the warm föhn is the fierce NE. wind of continental polar air which sweeps through the Alps between an anticylone in Central and east Europe and a depression in the west Mediterranean; it is known in Switzerland as the Bise. This scourge of winter and spring may continue, very cold and dry, for several days. It is perhaps most prominent in the south-west between Bienne and Geneva, under the front ranges of the Jura; Geneva is fully exposed and suffers all its fury when it whips up water from the lake and carries it over the shrubs and trees which may soon be encased in thick ice; on the average the NE. wind blows there on about 120 days in the year, fortunately not always with the full vigour of a bise. In districts where the bise is frequent and severe many houses are built without doors or windows facing north-east. Many Alpine valleys have their characteristic local winds by day or by night, but space does not admit of a description here.

The south valleys of the Alps are the warmest, owing to their latitude, their exposure and sunny skies, and some föhn influence on northerly winds that cross the mountains; the winter winds, however, often originate in high-pressure sys-

tems over the Alps themselves. The means for Lugano and Basel, at similar altitudes on opposite sides of the Alps, are:

MEAN TEMPERATURE

	Alt. *feet*	*January* ° F.	*July* ° F.
Basel	1,040	31	65
Lugano . . .	902	35	70

An important local influence in a system with an east–west trend like the Alps is exposure; the south-facing slopes enjoy a great advantage, which has visible expression in both the

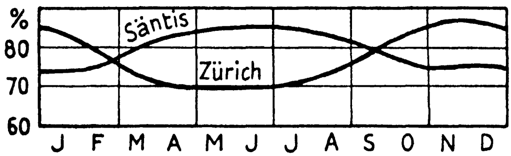


FIG. 106. Mean relative humidity.

natural vegetation and the agriculture and settlements of man. The contrast between the upper north-facing slopes (the schattenseit or ubac) still deep in snow, and the bare south slopes (the sonnenseit or adret) which are already warm in the bright and almost vertical rays of the midday sun, impresses anyone who makes his way through the mountains in spring.

Some effects of the mountain- and valley-breezes, which are prominent in settled weather, are mentioned in the next paragraph.

Cloud and Humidity. In winter during settled weather the valley-bottoms tend to be damp and foggy, mostly so in the long nights when the air, chilled to its dew-point, drains down the slopes and usually blows down the valleys ('the mountain-breeze'). The weather at such times may be gloomy under an unbroken ceiling of stratus cloud about 2,000 feet, at the inversion between the cold air below and the dry subsiding air above. The summits, on the other hand, rise high above the cloud-layer and often enjoy clear anticyclonic weather, bright sunshine, dry warm air. In the heat of summer the relation is reversed (Fig. 106); the valleys are hot and dry, and less cloudy (no more cloudy than the lowlands outside), while the summits, though clear at night, are usually hidden in thick cloud in the

afternoon, when the air brought in by the valley-breezes rises as it converges round the heights, cools, and condenses its vapour; on the Säntis the sunniest hour of the day in August is 0900 to 1000, just before the heavy mountain clouds form. Hence to find a bright sunny climate we must ascend from the valleys in winter and return to them again in summer. In the disturbed weather of fronts which sweep across from depressions in the north enormous masses of cloud may cover the whole range, valleys and summits, towering up even to 20,000 feet; this frontal weather is most frequent in autumn.

The driest air is found in different situations under different meteorological conditions. Some of the lowest humidities in the deep northern valleys occur with strong föhn winds, when the air can be so dry that villages have been burnt down owing to the wooden chalets easily catching fire. On the other hand, in the temperature inversions of anticyclonic weather the mountain-tops have subsiding air and are warm and remarkably dry and sunny. At such times the summits offer climatic attractions to invalids requiring bright invigorating air and sunshine rich in ultra-violet radiation. But equal advantages in a more accessible form are available in certain elevated valleys, as at Arosa and Davos. These resorts are indeed cold in winter like other valleys, and the range of temperature from day to night is large; Davos has the largest range recorded in Switzerland, and some of the lowest temperatures, lower than the Säntis and eclipsed only by Bevers and Andermatt:

MEAN TEMPERATURE, JANUARY

	Alt. feet	*0730*	*1330*	*Range 1330–0730*
Lucerne	1,634	29	35	6
Davos	5,121	16	27	11
Säntis	8,202	16	18	2

But though Davos is cold it rarely has the chilly wet fogs which often fill the lower valleys in winter, and the cold is of that dry type which invigorates. It is mainly its bright sunny skies which make the Davos winter climate famous, for it has only half as much cloud as Lucerne, and twice as much sunshine. The snow-clad valley enjoys clear deep-blue skies, crisp calm invigorating air, and long hours of sunshine which has the merit of containing a notably higher proportion of radiation

of short wave-length, thanks to the absence of moisture and dust-particles in the rarefied air, advantages which are prized by many seekers after health. But in summer it shares the cloudy skies and moist air of the tops, and has less sunshine than the lower valleys.

The following table shows the effects of different topographies:

	Alt. feet	Cloud, tenths, (mean of 0730, 1330, 2130) Jan.	July	Sunshine (hours a day) Jan.	July	Relative humidity, per cent. (mean of 0730, 1330, 2130) Jan.	July
Jungfraujoch	11,739	7	6	3·0	6·4	73	72
Säntis	8,202	6	7	3·6	5·2	75	85
Davos	5,121	5	6	3·0	6·5	80	73
Chur	2,001	5	5	2·3	6·8	90	70
Bern	1,877	8	5	1·9	8·0	86	72
Zürich	1,542	8	5	1·6	8·0	83	72

The difference in temperature between the north and south of the Alps has already been mentioned. The south is favoured in the other features also:

	Sunshine (hours a day) Jan.	July	Cloud (tenths) Jan.	July	Precipitation: January Amt.	No. of days	July Amt.	No. of days
Basel	2·1	7·5	7	6	1·6	10	3·5	13
Lugano	4·0	9·0	4	4	2·5	7	6·6	11

Basel and Lugano represent not merely the two sides of a mountain-range but two different regions, cloudy Central Europe and the bright Mediterranean.

Precipitation. The Alps have far more precipitation than the lowlands on both sides, but not nearly so much as lesser mountains near the sea. The valleys have less than the ranges which bound them, and the valley lines stand out plainly on the rainfall map. In Switzerland the rainiest (rain includes snow) areas are the mountain-groups which include the St. Gotthard and the Säntis, the latter with annual mean 110 inches; Sargans in the bottom of the Rhine valley at the foot of the Säntis has only 50 inches, rather less than half as much. The upper Rhone valley, with less than 25 inches, is the driest part of

Switzerland, as dry as the plains of south Germany and north Lombardy. In the eastern Alps the smallest totals, 30 inches and less, are in the great longitudinal valleys of the rivers Inn, Salzach, and Enns, and in the French Alps in the Tarentaise, the Maurienne, and the valleys of the upper Durance and its tributaries, which are wide and deep and enclosed by high ranges. The Engadine has a notably dry continental climate, with clear skies and relatively extreme temperatures. In the north and middle ranges of the Alps summer is the rainiest season, July the rainiest month, both on the summits and in the valleys.

In winter nearly all the precipitation is snow, everywhere except on the southernmost ranges where siroccos may give rain even up to 5,000 feet. The end of September sees the mountains, except in Provence, snow-covered down to 7,000 feet, the end of November down to 2,000 feet; in winter the snow-cover is almost continuous except in the lowest and the south-facing valleys. On the summit of the Säntis almost all the precipitation in the months November to April is snow, and at Davos rain is hardly ever seen from November to March, and snow occasionally falls even in June and August; in July alone is all the precipitation rain. In the lower valleys, at Altdorf for example, it never snows from the beginning of May till the end of September.

A depth of 20 to 25 feet of snow is not uncommon in the higher valleys such as the Engadine in winter, and 45 feet has been measured on the Säntis. Snow covers the ground in an average year for a fortnight at Geneva, a month at Basel, 6 weeks at Altdorf; at Davos for 173 days between mid-October and mid-May (mean depth in January 26 inches, in February 31 inches), at Innsbruck for 78 days, at Graz for 64 days, for over 6 months in the Upper Engadine, and for 10 months on the Säntis. These examples show that the depth and the duration of the snow vary greatly not only with the altitude but with locality. In general, districts with low precipitation in winter have a snow-cover of small and irregular depth and duration. The snow-line is about 9,000 feet in the western Alps, 10,500 feet in the drier interior ranges. Most of the road-passes are blocked from November till the end of May in an average year. Deciduous trees and agriculture extend up the valley-

sides to about 4,500 feet; then comes a zone of coniferous forests to about 5,500 feet, separated by grass slopes (alps) and bare rock from the perpetual snows.

The above description refers in the main to the Alps of Central Europe, from Vienna to Mont Pelvoux in Dauphiné. At the valleys of the Drôme and the upper Durance we enter a different mountain-world, in which Mediterranean influences become prominent in the dry landscape, and in the spread of maquis and poor types of shrub vegetation on the upper slopes (some of which are almost bare), in contrast to the humid north and east, famed for their green pastures in the valley-bottoms, well-watered mountain sides, and comparatively rich tree-growth; the south is a land of sheep, not cattle. Most of the rain falls in the winter half-year, often in heavy downpours in autumn, and the rivers roll along in devastating flood; but the total precipitation is much less than in the north, the summers are hot and dry with strong evaporation in the hot sunshine under the clear skies, and the rivers, without rain or glaciers or melting snow to feed them, shrink to feeble streams winding through wide belts of sand-banks; but where possible the valley-bottoms are irrigated and vines, olives, and fruit-trees flourish. Such is most of the basin of the River Durance, the more open parts of which have a mean annual precipitation of less than 35 inches. Only in the extreme south does the rain increase again on the ranges exposed to the moist winds of Mediterranean depressions; here groves of olive-trees near sea-level give way to chestnuts above and conifers above these.

The Major Climatic Regions of Central Europe

[*Note.* The following, like all general regional descriptions, can apply only in general terms to the average topography of the region. At altitudes above or below the average the climate is more harsh or more mild, more rainy or less, and the local influences, including good shelter or unusual exposure, may be appreciable.]

The main divisions (Fig. 107) are: I, the northern plain (part of the great lowland of the north of Eurasia), II, the central highlands, III, the southern plains (linked by the River Danube which flows through their midst), and IV, the upland region of the Balkan Peninsula in the far south-east.

Subdivision from west to east is required, based on the increasing continentality.

I. *The Northern Plain.* A more humid region than the other lowlands. The high latitude gives long days in summer, short

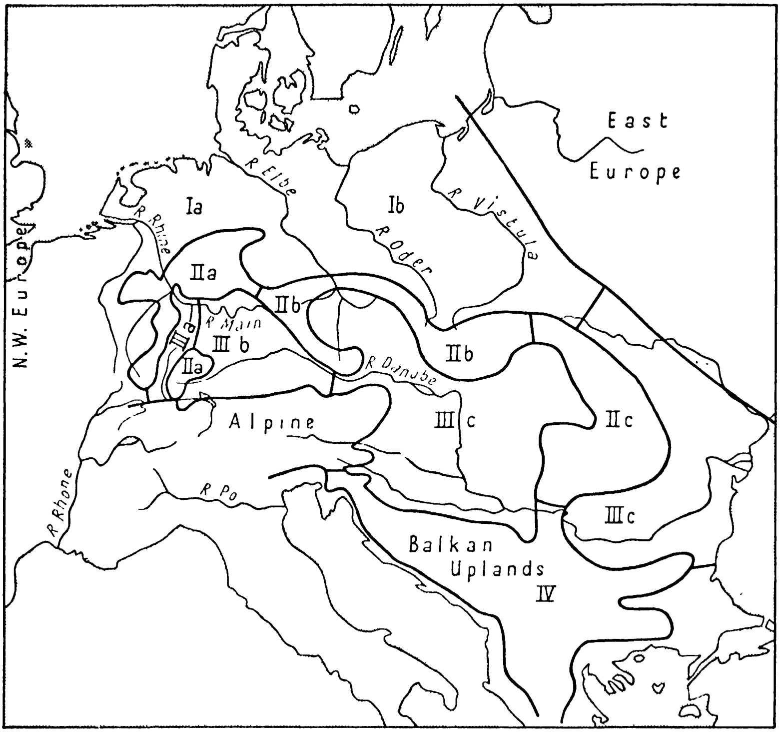


FIG. 107. Major climatic regions of Central Europe.

in winter. Summer is cool and short (mean monthly temperature in July about 65°; 3 months have means above 60°), winter cold, spring late and cool. Mean annual precipitation about 25 inches, most in summer and autumn, but well distributed over the year. This great expanse of plain is without climatic divides, but subdivision is arbitrarily but conveniently made by the January isotherm of 32° (actual temperature) into

(*a*) The region on the west, including Holland, Belgium, and north-west Germany, which has the damp and cloudy climate of north-west Europe, winters less cold than in the east (Janu-

ary mean 32° to 37°, rivers and harbours ice-bound only 1 or 2 days in an average winter, ground snow-covered less than 30 days), and a smaller range of temperature.

(*b*) The east, including most of the north German plain, with a continental winter (January mean below 32°, falling to 25° in the east; 3 months with means below 32°), much snow (ground covered for 30 to 80 days a year), harbours and rivers ice-bound for at least some weeks, 80 days in the extreme east; spring is cool and raw near the Baltic, but inland it is a bright season with many sunny days, and soon gives place to the warm summer with daily maxima often above 90°; autumn warm but damp; mean annual range of temperature about 35°. The increasing continentality eastward is shown by the duration of the ice-cover on the rivers—on the Rhine at Köln, 13 days a year, on the Elbe at Magdeburg, 30 days, on the Oder at Frankfurt, 43 days. The southern border of this division, the Börde, is a rich agricultural belt favoured both climatically in its warmer summers, due in part to shelter along the foot of the highlands, and still more in its fertile soil.

II. *The Central Highlands*. Conditions are largely determined by altitude and topography; the uplands are bleak and sunless, but the deeply incised valleys are sheltered, and the south-facing slopes along the Rhine and its tributaries favour vineyards; the northern valleys are cold and infertile in comparison; the mean annual precipitation is 30 to 40 inches. Of the subdivisions,

(*a*) The west, including the Ardennes, the Vosges and the Black Forest, and the central Rhine highlands, is the lowest, and most of the uplands at less than 3,000 feet have about 4 months with a mean temperature below 32°. But the Vosges and Black Forest are over 4,000 feet; while their steep valley-sides and lower uplands are thickly forested, the higher uplands, with their cool summers and long bleak winters, are bare windswept pasture; the precipitation is heavy, and much of it is snow, the lower valleys being under snow on the average about 30 days a year, the uplands about 170 days.

(*b*) The central division is the hill country surrounding Bohemia and the western Carpathians. These uplands rise to about 5,000 feet, and consequently have longer and colder

winters (4 or 5 months below 32°), with much snow lying late into the spring.

(*c*) The east, including the central and south Carpathians and Transylvania, is still higher, much of it above 6,000 feet, and the altitude, together with the more continental position, makes the winters very cold, with 5 months below 32°. But the drier air, brighter skies, and abundant sunshine are attractive features. In winter anticyclones there is often a sharp contrast between the damp cold in the valleys and the sunshine and warmth on the uplands.

III. *The Southern Plains.* (*a*) The western division is the small, but economically very important, rift valley of the Rhine from Basel to Frankfurt. Favoured by the shelter of the surrounding highlands it has early and warm springs, hot summers (July mean about 66°), and warm autumns; but winter is cold and foggy for the latitude, the January mean being about 34°. Vines, wheat, tobacco, and many temperate fruits flourish, maize ripens. Slope is an important factor, and the many south-facing slopes have specially advantageous conditions. The rainfall, 25 inches a year, together with the copious streams from the highlands, provide enough water for agriculture.

(*b*) The upper Danube and the Main basins, including much of Bavaria and Württemberg, mostly 1,500 feet above sea-level but below 1,000 feet in the Main valley and above 2,000 feet in the south. Winter is a bleak season on the higher lands, the January mean being between 25° and 32° in most of the region, and 3 months having means below 32°. Spring is late, but summer is warm and sunny for the altitude, the July mean being about 65°; the valleys, much favoured by their shelter from the piercing winds that often rage across the highlands, have very pleasant summers, though the winters are cold. The rainfall, rather more than 30 inches, has a pronounced summer maximum, June, July, and August having about 4 inches each.

(*c*) The middle and lower Danube plains below Linz, a transition region between Central Europe and the true steppes of south Russia. The climate is continental, a prominent feature being the large range of temperature. Winter is very cold on

the plains (—29° has been recorded at Kecskemet, altitude 430 feet), and bleak winds sometimes sweep the open treeless expanses, but calm and bright sunny days are frequent; the January mean is about 27° (3 months below 32°). Snow is not infrequent, though usually of little depth; the land is snow-covered for about 40 days in the north (41 days at Vienna), 30 days in the south (31 at Szeged), but the snowy period is not usually unbroken. The middle Danube bears ice-floes from mid-December till early February, but is not frozen over. Inversion-fogs are frequent in winter calms. A rapid change sets in after March, spring comes on apace, and the summer days are hot and sunny, with pleasantly dry air; the means are about 70° in July and August, and exceed 60° in each of the 5 months May to September. The precipitation is from 20 to 25 inches, but falls to 15 inches on the coasts of the Black Sea, with a marked maximum in May to August; much of it falls in short but heavy afternoon thunderstorms, the number of rainy days being small. The early summer rains favour wheat, the main crop, which is harvested in July; late summer has little rain and strong evaporation, and the land dries out. Near the Black Sea the secondary rainfall maximum which is a feature of the Mediterranean region appears.

IV. *The Balkan Uplands* consist of an elevated block, much of it well over 6,000 feet, with many long deep valleys. The whole region is cold in winter with frequent keen frosts, even the valleys having a January mean below 32° (Skoplje, 29°); in some years snow lies deep everywhere for many weeks. But summer is hot, the July mean in the lower valleys exceeding 72°. Thus in spite of proximity to the sea the climate is continental. The mean annual precipitation is about 30 inches on the uplands, 20 inches in the valleys, with a marked summer maximum (in strong contrast to the autumn and winter maximum of the adjacent Adriatic and Aegean coasts). Prominent local winds of this region are the Kosava, which blows strongly from between E. and S. through the Iron Gate or down the Morava into the south Hungarian plain, in its typical form a cold wind associated with the depressions of winter; and the Vardarac, a wind of the mistral type, which sweeps down the valley of the Vardar to the Aegean in winter.

CHAPTER XXX

THE MEDITERRANEAN LANDS

THE Mediterranean basin, which has seen the rise of so many of the great civilizations of the world, will always command special attention. The physical aspects are of no less fascinating interest than the human. The climate, with all its local

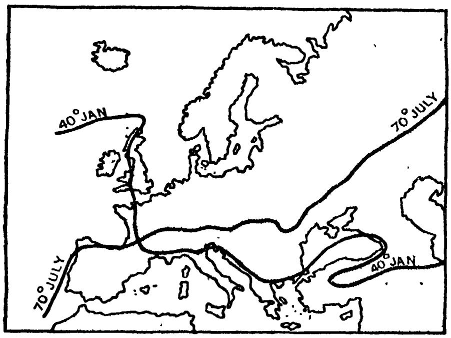


FIG. 108. Mean isotherms.

differences, possesses an essential unity and individuality among the climates of Europe, and it has produced a very characteristic type of vegetation. The environment was highly favourable for the early development of civilization, and the wide extension of the inland seas, and the climate to which they give rise, have always been among the great natural advantages of the continent.

The Mediterranean climate has three outstanding features: (i) most of the rain falls in the winter half-year, and drought, more or less complete, prevails in summer. The periodicity is much stronger than in the rest of Europe, but the drought does not last more than 3 months in most of the region; (ii) the winters are not only rainy but mild; the coldest month has a mean temperature above 40°, and in much of the region above 50°. Summer is very hot as well as dry, at least 3 months having means above 70° (except in the oceanic west), and in Africa the July mean exceeds 85°. Fig. 108 shows that in winter the west of the British Isles is as warm as North Italy, but the course of the July isotherm of 70° excludes Britain from the

Mediterranean climatic province. On the other hand, the south-east of Europe is as warm as Italy in summer, but the winters are long, cold, and dry. Perhaps the best indication of the extension of the Mediterranean climate is given by the distribution of the olive-tree, one of the most characteristic elements in the Mediterranean vegetation (Fig. 109); (iii) the bright sunny skies—almost cloudless in summer, and far less cloudy even in winter than the skies of north Europe—are an essential feature, and probably of far-reaching influence on

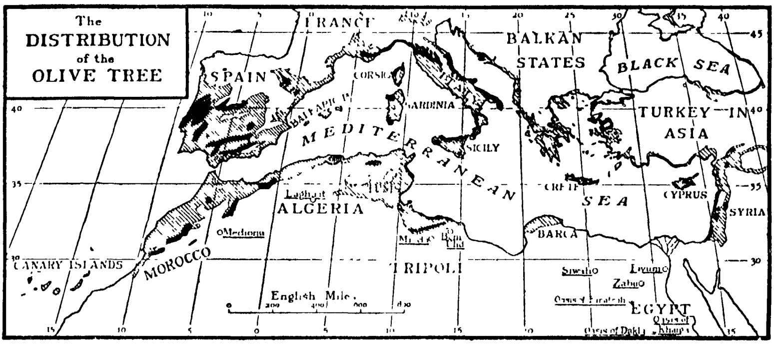


FIG. 109. Black areas are those of most intensive cultivation.

human development. The hot sunny weather is ideal for ripening the fruits for which the region is famous.

PRESSURE AND WINDS

The general features are described on pages 302–5, and some details are now given for summer and winter, the transition seasons being omitted through lack of space. On the coasts in particular, the main air-streams are much modified; prominent local winds are treated on pages 357–61. The Mediterranean is a large sea, 2,400 miles long, with two major natural divisions, the west basin west of Sicily–Tunisia, and the much larger east in a lower latitude and more continental position. The former has three subdivisions, the Tyrrhenian Sea, the Balearic Sea west of Corsica–Sardinia (including the Gulfs of Lions and Genoa, each with its own peculiarities), and the narrow south-westward extension to Gibraltar which may be named the Alboran Sea. The east basin, about 1,400 miles long, has one subdivision west of Crete and a narrower, but still 350

miles wide, in the east round Cyprus. The Adriatic, extending north to lat. 46° N. (and belonging almost as much to the west as to the east basin), and the Aegean are prominent annexes, and the Black Sea may also be included, but its position far to the north-east imposes strong differences of climate. These compartments are so large and so distinct that they form meteorological units.

Summer. The controlling pressure-systems, the Azores anticyclone and the monsoonal low-pressures of south Asia with

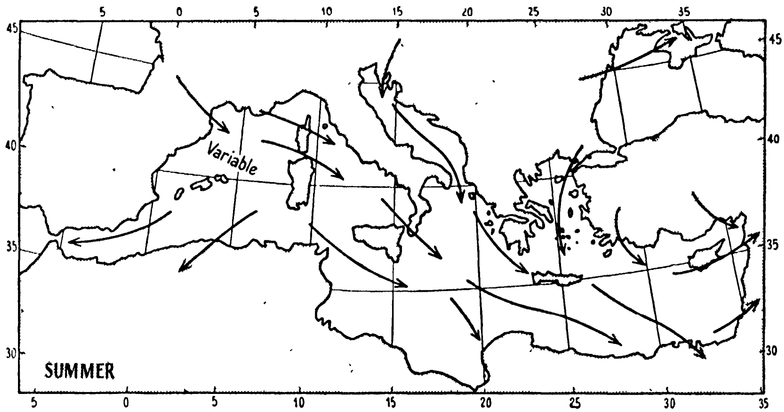


FIG. 110. Mean streamlines, summer.

their extension over the Sahara, direct the main streams of maritime tropical air; minor irregularities, depressions, are few in the west and almost absent in the east Mediterranean (Fig. 110). In the Balearic Sea the prevailing (but by no means constant) winds are NW. and N. in the north, NE. and E. in the south, between the Azores anticyclone and the low pressures in the Sahara. The Alboran Sea and the Strait of Gibraltar have prepondering easterlies ('Levante', 'Levanter', or 'Llevante' when of long fetch, and 'Llevantades' when specially stormy), with westerlies next in frequency, the wind showing the usual tendency to take the direction of seas and channels.

In the east Mediterranean the winds are dominated by the Asiatic monsoonal low-pressures and blow from NW. and N. (W. and SW. on the coasts of Palestine and Syria); they are mainly light or moderate, rarely rising to gale force on the

open sea though sometimes round Cyprus, and remarkably steady in direction. Of the annexes, the Aegean has N. winds Etesians (in Turkish, Meltemi) of notable constancy (80 per cent. frequency round the Dodecanese in July and August). They are moderate to strong, occasionally of gale force (this more often in the north than in the south); strong and even violent squalls often rush down to the sea on the lee side of steep islands. Temperature and humidity are pleasant, the deep-blue

WIND DIRECTIONS, MEAN PERCENTAGE FREQUENCIES

(Means of observations at 0700, 1300, 2100, local time; Jaffa 0900 only)

		N.	*NE.*	*E.*	*SE.*	*S.*	*SW.*	*W.*	*NW.*	*Calm*
Marseilles,	Jan. . .	2	20	18	9	2	4	9	36	1
	July . .	1	10	5	7	6	16	24	31	0
Gibraltar,	Jan. . .	1	2	28	7	1	7	25	24	5
	July . .	0	2	37	9	3	11	21	11	6
Algiers,	Jan. . .	13	7	11	6	8	14	27	13	1
	July . .	26	23	23	5	2	3	7	10	1
Naples,	Jan. . .	22	20	13	5	10	9	12	9	—
	July . .	8	6	11	4	13	24	27	7	—
Malta,	Jan. . .	6	14	6	11	3	14	11	27	8
	July . .	11	20	4	7	2	4	5	35	12
Istanbul,	Jan. . .	22	27	1	1	15	18	8	3	11
	July . .	22	54	4	1	2	3	1	2	11
Thira (Santorin)	Jan. . .	30	12	6	6	7	12	16	11	0
	July . .	46	8	1	0	1	3	19	22	0
Izmir,	Jan. . .	17	8	8	2	15	0	1	1	48
	July . .	18	2	11	0	12	1	26	1	29
Alexandria,	Jan. . .	12	9	7	6	6	15	16	18	12
	July . .	30	4	0	0	0	0	11	52	3
Jaffa,	Jan. . .	5	8	8	15	32	7	2	4	20
	July . .	0	0	1	0	0	56	30	8	8

skies are almost cloudless, and white-crested waves swing across the blue seas.

In the Adriatic also the winds tend to follow the axis of the sea, blowing with fair constancy from NW., usually light or moderate and very rarely strong except in the north; they are sometimes called Maestrale. In the Black Sea the general winds are northerly, light or moderate and occasionally of gale force. The Sea of Marmara and the Straits have light to moderate N. and NE. winds, deflected to follow the coasts.

Land- and sea-breezes modify the general directions, in

places almost to the point of reversal; the on-shore wind in the day is strong, the land-breeze at night weak, sometimes falling to a calm. The remarkably constant W. and SW. winds of the coasts of the Levant are in large part sea-breezes; their shallowness is shown by the upper winds being between W. and N. above 2,000 feet; Anatolia and Iberia have almost constant on-shore winds blowing to the hot interiors.

The table above gives mean frequencies for a number of

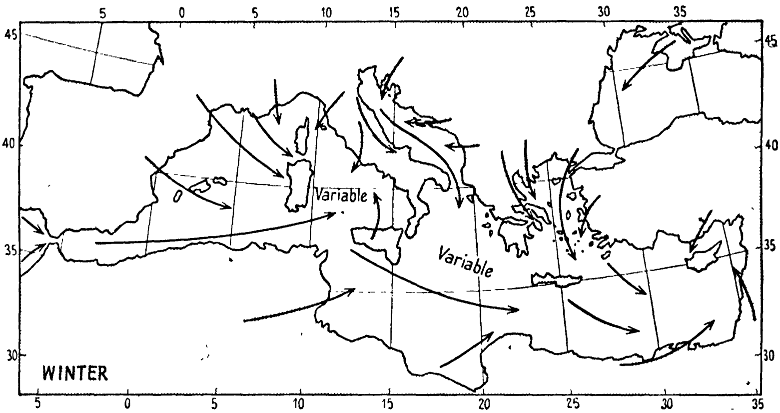


FIG. 111. Mean streamlines, winter.

stations, but owing to the strong topographical effects no land station is representative of a large area.

Winter. The meteorology is much more complex than in summer, the region being within the influence of the westerlies. General streamlines can be recognized (Fig. 111), but the winds are cyclonic, variable in force and direction, and bringing air-masses of different types. Near coasts two local factors are the tendency to blow along-shore as in summer (off some prominent headlands the winds are sometimes blowing from opposite directions on the two sides, and are known as Contrastes); and the land-breeze, in places stronger than in summer (the sea-breeze is of little strength in winter). The former is prominent in the south, the latter in the colder north. Shallow depressions tend to persist on the large 'compartments' of the Mediterranean Sea, separated by tongues of higher pressure on the peninsulas of Iberia, Italy, Greece, Anatolia, and the winds are clearly related to them; in terms of the daily weather, depres-

sions tend to travel over, or remain almost stationary on, these seas, with the result that the west coasts of the peninsulas have southerlies, warm and rainy, while the east have cool dry northerlies, but changes of wind and weather are frequent.

In the west Mediterranean as a whole the prevailing winds are westerly in the south, northerly in the north, north-westerly in the west, north-easterly in the east. To add some prominent details, the north, particularly the Gulf of Lions, suffers the full force of mistrals from north-west (p. 357) and marins from south-east (p. 361), and is notorious for its wild weather in winter and spring. The Riviera, under the shelter of the Alps, has much less wind and better weather, but the Gulf of Genoa is exposed to northerlies of almost mistral intensity. The Tyrrhenian Sea has variables, light or moderate and rarely of gale force; on the Italian coast south to Naples NE. winds predominate. The Spanish coast, where the prevailing winds are NW., often has strong SW. 'Vendavales', at times of gale force, which may give heavy rain and high seas. In the Alboran Sea and the Strait of Gibraltar the wind is generally between SW. and NW., but easterlies ('Levanters', usually with bad weather) also are frequent. The passage between Tunisia and Sicily–Sardinia has north-westerlies, often strong.

In the east basin the general winds are westerly in the south, northerly on the coasts of Europe and the south coast of Anatolia, south-easterly in Palestine, north-easterly in Syria, under the control of the low pressures over the sea. As is the case in the west basin the winds are cyclonic, variable in direction and force; they are often strong and are liable to reach gale force in the open sea, and more frequently on the Libyan and east Egyptian coasts and round Cyprus (the sea on the north and east of the island has about 12 days with gales, most from the north-east, in the winter half-year). The Aegean has its own cyclonic circulation, prevailing E. and SE. on the Anatolian coast, NE. off the Dardanelles, N. off Macedonia, NW. and N. off Greece. The wind is moderate to strong, with occasional gales; on the Macedonian coast gales are fairly frequent, and are very strong when cold air-masses sweep down the valleys from the highlands with cloud and

rain (unlike the strong winds of summer with their bright skies). The Adriatic also has its own low pressures with easterlies and south-easterlies on the Balkan coast, north-westerlies on the Italian side, but these are only the most frequent of the cyclonic variables. The winds are usually moderate but may be strong even to gale force, especially the bora of the north-east (p. 358).

The Black Sea is another lake of low pressure, between the high pressures of Russia and Anatolia, and is traversed by many depressions following tracks 6 and 8 (Fig. 112) and by others which have come from north-west Europe or the Baltic; they tend to deepen over the Black Sea, and to slow down or remain stationary as they reach its east end. Northerlies prevail in the north, winds between S. and W. in the south, but the winds are variable, warmer S. and SW. blowing, with cloud and rain, in front of depressions, strong and persistent N. and NE., not seldom rising to gale force and usually bringing snow, behind. These bitterly cold northerlies from the bleak open steppes are a major feature of the Russian coasts; the shelter of the Yaila Mountains makes the comparatively genial climate of Yalta and the neighbouring coast. In strong contrast the open sea of Azov has many long and fierce gales, and the coast under the Caucasus is notorious for its bora (p. 266). The Sea of Marmara and the Straits have similar winds to those of the Black Sea; they are notably strong and blustering in the Straits.

Some of the Mediterranean depressions have their origin over the sea itself, but most are secondaries to large low-pressure systems of north-west Europe, developing into definite Mediterranean depressions over the Gulfs of Lions and Genoa; other favoured areas are the east Mediterranean south of Anatolia, and, especially in spring, the north-west of Africa south of the Atlas Mountains. Sometimes primary depressions enter the Mediterranean from the Atlantic over south-west France or the neighbourhood of the Strait of Gibraltar; a long 'trailing' cold front often extends east–west in winter through the Strait, and is an important weather factor since series of secondaries develop on it and give south Spain and north-west Africa bad weather with rain as they travel eastward. Many depressions,

notably in the north-west, are 'lee depressions' formed over the Gulf of Genoa and north Italy by the interception of a polar current by the Alps, the convex curve of that system deflecting the lower strata of the approaching air to west and to east, to the Rhone valley in which it appears as the mistral, and to the Danube lands whence part descends to the Adriatic as the bora. These depressions are responsible for massive cloud, very

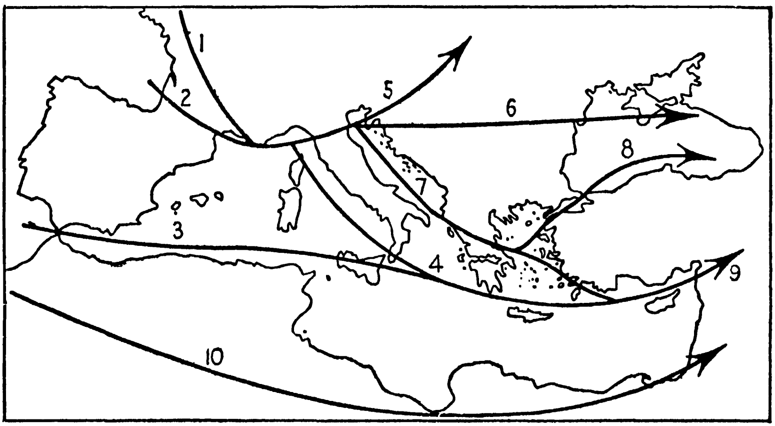


FIG. 112. Generalized tracks of depressions, Mediterranean region.

heavy rain, and turbulent air over Lombardy and the adjacent Alps.

Depressions are considerably more frequent in winter and spring (rather more in spring than in winter) than in summer and autumn. The east basin has about three-quarters as many as the west (a smaller proportion in summer), and not only are the summer and early-autumn depressions less numerous, they give less stormy weather, so that summer is a long fine season of blue skies, high temperatures, and little or no rain; in the west the occasional disturbances make the weather more variable.

The depressions tend to follow, approximately, certain belts or tracks, in particular those indicated in Fig. 112, but, as in other regions, their centres and fronts wander so much that generalized tracks must be largely arbitrary. All the tracks are followed in all seasons, but with seasonal preferences. Track 3 is frequented all the year; those over the Gulfs of Lions and Genoa, the Adriatic and Tyrrhenian Seas, in winter and spring;

track 8 mostly in spring, and track 9 in winter (only irregularly in autumn, a serious matter for Syria, whose agriculture is much dependent on autumn rain), tracks 5 and 6 in spring and early summer (the spring and early-summer rains of the Danube lands are associated with them); on track 10 spring is decidedly the favourite season, a result being the spring rains of the Atlas highlands and the khamsins of Lower Egypt. Most depressions divide, some more than once, and the various secondaries advance on different tracks, so that it is the exception for a system to follow for any great distance the track on which it starts.

It is the waters of the Mediterranean Sea that maintain the winter heat and moisture and hence the lower atmospheric pressure to which the winter conditions are due. Thus the Mediterranean climate is the gift of the Mediterranean Sea, and is found only on its shores. In the interior of the peninsulas the climate becomes more continental. The mountain ranges which enclose the Mediterranean are sharp climatic divides.

Parts of the Mediterranean are windy for the latitude both in summer and winter; gales are frequent, often of some violence and of several days' duration in the stormy depressions of the winter months, the direction of the wind changing as the depression passes; even in summer the winds can rise to gale force:

On the islands of the Greek Archipelago the north winds blow with such force in summer that in many places trees cannot grow on the high ground. In the summer storms the wind remains constant in direction, and does not veer as it does in north Europe. Such a storm on the Mediterranean is a magnificent sight, and a striking one for those who are accustomed to associate dark skies, driving clouds, and showers of rain with the idea of a storm. Here the sky is deep-blue, and the sea appears indigo, almost black, as the waves roll along with silver crests from which the wind tears shreds of foam. But in winter storms are much more frequent in the Mediterranean, and then the winds are changeable, and the weather is overcast and rainy. Small vessels are far more afraid of the veering winds of the winter storms than of the Etesian winds of summer, which are constant in direction, but often so strong that it is impossible to sail north against them (PHILIPPSON).

The strong winds of summer result from a temporary steepening of the normal barometric gradient; those of winter are

cyclonic round the depressions which pass along the Mediterranean basin.

Local Winds

The many travelling pressure-systems give cyclonic winds of force, direction, and persistence appropriate to their gradients and movements. Owing in large measure to the topography certain local winds are prominent in their effects on the life of man on land or at sea, and have received names, many of them of some antiquity in this region of ancient civilizations where navigation has long been a leading art.

Cold Winds. The best known is perhaps the Mistral of the Gulf of Lions; a similar name, Maestrale, is applied to cold winds in other regions. The mistral, the 'masterful' N. wind, often rushes down in winter in violent gusts to the usually warm littoral between the Ebro and Genoa, and is very unwelcome in the lower Rhone valley below Donzère, where the trees bear the sign of its violence in their set towards south-east, gardens are enclosed by close shelter-belts of cypress, and the humbler dwelling-houses have doors and windows only in their south-east walls. Such is the force of the mistral that railway trains have been blown over in the Rhone delta. The wind depends on the topography, a mountain-range deflecting it or at least breaking its force. It blows throughout the year, but is most prominent in winter and spring; statistics of frequency are not of much value unless 'mistral' is defined with precision, but a mean of about 100 days a year is given for Marseilles, in a specially exposed district, where a velocity of 83 miles an hour has been recorded. Some mistrals are of wide extent, covering the coast between Barcelona and Genoa, the Gulf of Lions (with squalls up to 100 miles an hour) and the Balearic Sea, and even crossing the Mediterranean to the African coast; violent down-draughts occur in the lee of steep shores. A more local type blows, violently enough, down the Rhone valley from the neighbourhood of Valence without much spread to east or west.

Meteorologically the mistral is essentially a strong polar current between a large anticyclone, sometimes far north, sometimes the Azores anticyclone covering west France, and a depression on the Gulfs of Lions and Genoa. The effect of the

barrier presented by the Alps to the polar air-stream is mentioned on page 355. As the cold front passes there may be thunder, with heavy snow in winter, but behind the front the mistral current is dry and the sky usually clear. The force of the wind is intensified by the topography as it blows down the Rhone, and part of the air descends katabatically from the Central Plateau of France, the Cevennes, and the Alpine valleys, all very cold and often snow-covered; it is noteworthy that the wind frequently fails to obey the direction and force indicated by the isobars, and appears to be governed largely by the local surface temperatures and topography.

The mistral may be of short duration, but it usually lasts for several days, perhaps with interruptions. On the coast it is stronger in the forenoon than at night. The cold, at times considerably below freezing-point, of a winter mistral is felt keenly by both the human and the plant inhabitants of a coast which normally enjoys less rigorous conditions; the dry air intensifies the physiological cold, and the bright sky tends to be an added irritation. In summer it is much less cold, but the contrast with the normal temperature of the season may be almost as prominent. The shelter of the Maritime and Ligurian Alps is the great climatic asset of the Riviera. Off Catalonia strong polar winds from between north and west, which may be part of a mistral current, are called tramontane or maestrale; they sometimes persist for weeks.

The Gulf of Genoa is subject to mistrals, and the maestrale of Genoa is a local wind similar to the local mistral of the Rhone valley; it is a very cold, but shallow, current of gale force derived from high-pressure systems in Lombardy, which sweeps through the pass in the range behind the town. It is most violent over the harbour in the early morning, and is one of the climatic scourges of the district.

Another similar, and very notable, wind afflicts the head of the Adriatic, and indeed all the Dalmatian coast from Trieste to Albania; it is known as the Bora (*boreas*, the north wind). As in Provence a warm sea is in close proximity to a cold land, the thermal gradient being one of the steepest in Europe (Fig. 114). In the preceding days abnormally cold air has been stagnating in the valleys of the Karst and the Dinaric Alps, probably in an anticyclonic calm; the air is often of remote polar

origin (as we have seen to be the case with the mistral). A depression appears on the Adriatic and the icy wind descends to the coast in irresistible blasts, exceeding 100 miles an hour in gaps in the ranges and on coasts backed by steep slopes, notably at Trieste where winds recorded as bora blow on the average on 39 days a year. The cold front passes with heavy cloud, snow or rain, but the polar current behind it usually has clear skies and dry air. In strong boras ships have to leave their anchorage at Trieste and seek shelter down the coast; the Gulf of Kvarner (Quarnero) is notorious for navigation, and the wind even precludes agriculture on the exposed islands.

Cold dry polar winds are frequent in winter on the north of the Aegean also, blowing down the Vardar valley (whence their name Vardarac).

The Gregale (the 'wind from Greece') of Malta and its neighbourhood is a strong NE. wind, generally between a large anticyclone in the Balkans and a depression over north Africa, without any special topographical influence. It is a polar current with variable weather, skies sometimes cloudless, sometimes heavy with rain and mist, most prominent in spring and autumn; and the high seas running into the harbours which lie open to the north-east may give serious trouble to ships. Similar winds ('Levante') blow on the Spanish coast and off Algeria, sometimes with gale force and very bad weather.

Tramontana is a name of loose application in the north-west Mediterranean to N. and NE. winds of cool polar air under a clear sky; the name is common in Italy.

Hot Winds. The middle and south of the Mediterranean are subject to local winds, in quality the opposite of those of the north. They may be grouped under the name Scirocco, but they are so prominent that they have local names—leveche in south-east Spain, scirocco in Algeria, Palestine, and Syria, chili in Tunisia, ghibli in Tripoli, khamsin in Egypt and Malta; when strong they are called simoom in the south-east. They owe their characteristics to their origin in the hot deserts of north Africa and Arabia. As a depression passes along the Mediterranean the tropical air of the scirocco in front of it may be derived from the desert hundreds of miles to the south, and is then very hot and dry and carries much dust and sand. The wind

is most prominent in spring, when depressions are numerous and the Mediterranean is normally much cooler than the desert; it sets in progressively later from west to east as the depression travels east, appearing 4 or 5 days later in the Levant than in Algeria. After blowing 1 or 2 days, or occasionally longer, it is replaced by cool polar air in rear of the depression. The high temperature (as high as 110° on the African coast) and low humidity continue through the night as well as the day, and in extreme cases do much damage to vegetation; but on some nights a remarkably heavy dew is beneficial to plants on the north African coast, in Malta, the Riviera, and elsewhere.

These desert winds may reach the north of the Mediterranean, but much modified by cooling and the absorption of vapour over the sea; when strong they cause a rise of several feet in the sea-level on the north coasts. In the Adriatic and the Aegean (where they are called gharbi) they are often of gale force, but warm, damp, and enervating, and give thick weather, sometimes fog, copious dew, and heavy rain (very heavy on mountainous coasts) which may contain red dust from the Sahara. But the leveche of south-east Spain is hot, dry, and dusty, like the scirocco of Algeria.

The abrupt change when the cold front of the depression passes with its wild gusts of polar air and heavy rain or snow, the forerunner of a mistral or a bora, has already been described. While the moist and muggy scirocco is blowing in Italy and the Adriatic, the cold dry mistral may be sweeping over the Rhone delta, the depression which is the cause of both winds lying over the Tyrrhenian or Adriatic Sea. If the scirocco descends from mountains its heat and dryness are intensified. This is the case on the north coast of Sicily, where the highest record at Palermo, 120° (relative humidity 10 per cent.), occurred during a scirocco, and 95° may be exceeded even in the night. During the dry scirocco of north Sicily

the air is misty, the sky yellowish to leaden, filled with heavy vapours, through which the sun can be seen only as a pale disk if at all. Man feels languid and oppressed, and disinclined for mental activity, and animals also suffer from these hot dry winds. Every one stays at home as much as possible and does nothing. When the scirocco is specially hot, its scorching breath does great injury to

the vegetation; the leaves of the trees curl up and fall off in a few days, and if it sets in when the olive trees and vines are in blossom a whole year's harvest may be lost (FISCHER).

The very high temperatures with SE. winds on the Syrian coast have a similar cause. The frequency of sciroccos depends on that of the depressions which cause them. In the west Mediterranean they are noticeable on about 50 days a year, in all seasons, but in the Levant they are rather less frequent, most being in winter and spring; from June to October they are very rare, since depressions are almost absent from the east Mediterranean; the dry scirocco of the north African coast is prominent in spring and winter, the rainy scirocco of the north Mediterranean in winter.

The marin, a frequent wind of the scirocco type in the Gulf of Lions and its neighbourhood, deserves mention. It blows from SE. in front of depressions, sometimes with gale force and usually with warm cloudy weather and heavy rain. In many respects it is the opposite of the mistral; in much of the north-west Mediterranean SE. winds are next in frequency after NW. The marin is not without its dangers to ships on a lee shore. It often blows strongly across Languedoc and through the gap of Carcassonne into Aquitaine, where it becomes the Autan; 'ce vent est chaud et pesant, lourd, il engourdit et abat les hommes et les animaux. Il rend la tête pesante, il ôte l'appétit et paraît gonfler tout le corps'—such is the description of the autan by Astruc in 1740. In its typical form it has a pronounced föhn character, developed when the damp marin crosses the depression between the Montagne Noire and the Pyrenees, only about 600 feet above sea-level but its effect is probably intensified by the narrowing of the lowlands, which increases the marin at times to a gale and gives it a föhn character when it descends on the west. Naturally the autan varies in force and weather, but in some parts of the south-east of Aquitaine the name is applied to winds that seem to have no relation to the true autan.

TEMPERATURE AND WEATHER

Summer. The region is akin to the Sahara in summer. The sky is almost as cloudless (cloud amount falling below 2 tenths in June and July in the south-east and below 3 on most of the

north-west coasts), and the sunshine almost as abundant, but the expanse of sea prevents the parching heat and drought of the Sahara being realized to the full. Temperature, however, is high, highest in the south and east, lower near the Atlantic (Fig. 113).

Everywhere the summer days get rapidly hotter with distance from the sea (see table on page 363); the mean (sea-level) isotherms for July (Fig. 95) show the greater heat in the interior of the peninsulas, the increase being similar in all.

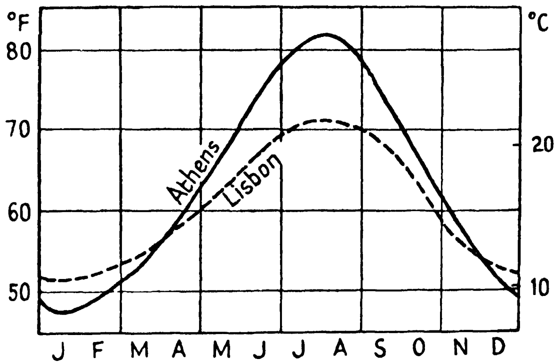


FIG. 113. Mean temperatures.

A description of the summer weather in Greece is given by Philippson:

Day after day the sun pours down its fierce rays on the thirsty earth from a deep-blue sky, in which only occasionally is a little white cloud seen. Very rarely is there a passing shower of rain, and it evaporates at once. The direct rays of the sun are powerful, and objects exposed to them are heated to an astonishing degree. In the shade the air temperature reaches 105°, but the sand on the dunes of Phalerum may heat to 160°. When it is calm the air shimmers over the parched land, at other times the north wind carries clouds of dust over the plains in great whirls. Distant islands and promontories float high above the sea in mirages. Most rivers and streams dry up, grasses and herbs wither, and the harvest is gathered in early in the season. The ground cracks and lies naked to the glare of the sun. The landscape, which in spring was gay with waving fields of corn or the green of sprouting vegetation, now shows the harsh colours of the desert, and the vineyards and maize fields and irrigated gardens alone preserve their bright verdure. In the midday hours all life seems to stop, men and animals

drag themselves to shady places to rest, and only the shrill monotonous cicada like the sound of a rattle is heard. However, the dryness of the air and the rapid evaporation make the heat bearable, given shade from the sun. The heat is intense, but not sultry. Moreover, the air is almost always in rapid movement owing to the Etesian winds or the sea-breeze. The heat is far more oppressive in the sheltered valleys and the basins of the interior, and in moist irrigated agricultural districts, than on the coasts, though even the

MEAN TEMPERATURE

		Coolest month (January)				*Warmest month (July)*						
	Alt. feet	*Mean for month*	*Mean daily max.*	*min.*	*range*	*Mean for month*	*Mean daily max.*	*min.*	*range*	*Mean annual range*	*Absolute extremes min.*	*max.*
Coasts												
Lisbon	321	51	56	46	10	71[2]	80	64	16	21	29	103
Barcelona	136	47	55	40	15	75[2]	83	62	21	28	15	99
Cadiz	46	52[1]	62	50	12	76[2]	83	69	14	24	29	103
Gibraltar	90	55	61	49	12	75[2]	84	69	15	26	30	100
Marseilles	246	43	52	37	15	72	83	61	22	29	11	101
Cannes	coast	48	57	39	18	74	83	65	18	26	21	95
Genoa	177	46	49	42	7	75	81	70	11	29	17	95
Palermo	234	50	58	47	11	77[2]	82	74	8	27	29	114
Venice	82	37	41	32	9	75	82	68	14	39	14	97
Ancona	52	42	47	38	9	78	84	71	13	36	21	102
Malta	185	53	59	51	8	77[2]	85	73	12	24	34	105
Zakinthos (Zante)	23	53	57	47	10	81	86	72	14	28	29	105
Athens	351	47	54	42	12	80	90	72	18	33	20	109
Istanbul		40[1]	46	38	8	74	82	67	15	34	17	100
Interior												
Saragossa	673	42	—	—	—	76	—	—	—	34	5	112
Madrid	1,965	40	48	33	15	78	93	61	32	37	11	111
Seville	98	50	—	—	—	83[2]	—	—	—	33	22	122
Florence	240	41	47	36	11	76	87	65	22	35	—	—
Rome	208	45	52	38	14	76	87	65	22	31	17	108
Volo	26	45	52	38	14	81	89	69	20	36	19	105
Larissa	249	42	—	—	—	81	—	—	—	39	9	113

[1] February. [2] August.

interior, at any rate at the foot of the higher mountains, is not without a regular respiration; by day the wind blows up the mountains, but hardly has the sun set when the first puffs of cool wind descend from the heights, so that some protection against chill is necessary. At night the heat is rapidly radiated, but nevertheless it is always warm, and dew is rare. Nothing is more magnificent than a summer night on the coast of Greece, when the land-breeze wafts down cool fragrant air, and the stars sparkle with a fire never seen in our latitudes. The natives sleep in the open air to avoid the musty air and the insects in their houses. Summer is the time of the brightest light, and the most glorious play of colour, especially in the evenings. Every line in the landscape, even in the far distance, is sharply cut, and every tint in the rocks shows up brightly since there is little vegetation to hide it.

Winter. But if the Mediterranean lands recall the Sahara in summer, which continues till mid-September, winter brings a close resemblance to north-west Europe. The pressure-distribution is neither so regular nor so constant as in summer; with the encroachment of the westerlies the weather becomes cyclonic, cloud increases rapidly to a monthly mean of 5 or

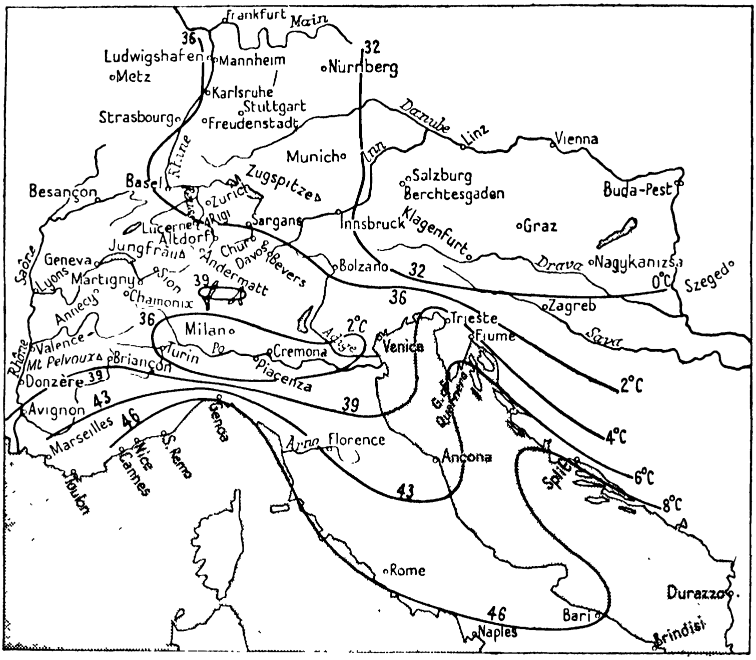


FIG. 114. Mean isotherms, January.

6 tenths in October to April, temperature falls, and the rainy season starts.

The mean temperature on the coasts in January is about 43° in the north, increasing to 50° in the south (55° in the south-east). The anti-clockwise circulation of the Tyrrhenian, Adriatic, and Aegean Seas sends warmer water along the west of the peninsulas than the east, and the prevailing winds carry the warmth over the west coasts, the isotherms running south and then northward again in the east (Fig. 114).

The more local controls, diurnal and annual, on coasts and in interiors, are shown by actual data; the cold of winter, like

the heat of summer, increases inland, but the effect of altitude makes comparison difficult, and moreover the true Mediterranean climate is restricted to the coasts.

Most of the Mediterranean coasts have frost in winter; the mean is 25 days on the coast of the Gulf of Lions and more on the north Adriatic and Aegean coasts. It is not rare in the north of peninsular Italy, but seldom occurs round Greece and never at Gibraltar, Malta, on the south coast of Sicily, and on the islands in the south of the Aegean Sea. The mistral and similar polar winds bring temperatures well below freezing-point; in the unusually cold winter of 1891 the inner parts of the harbours of Lisbon and Toulon were ice-bound. The interiors of the peninsulas are naturally liable to much lower readings than the coasts.

The power of the sun's rays, both direct and reflected from the sea, and the strong winds cause large local differences in climate according to exposure to the one and shelter from the other. The Riviera is specially favoured, with a mean January temperature only 5° lower than on the Algerian coast 500 miles south. Leaving the shelter of the mountains round the Gulf of Genoa, we must go south along the west coast of Italy as far as Naples to equal the mean temperature of Cannes. The Alps provide a similar shelter for the Italian lakes, the Dinaric Alps for the Adriatic coast, and the Yaila Mountains for the south coast of the Crimea (the January mean is 4° higher at Yalta than at Sevastopol, only 40 miles distant); the chief winter resorts of the Mediterranean are situated either in these sheltered positions in the north or else far south.

Autumn is everywhere warmer than spring, a true maritime feature. The moist heat of October can be more oppressive and unhealthy than the hotter but drier weather of July. Spring has cold spells reminiscent of winter, as trying as the cold spells of spring in north Europe; the polar air is warmed if it crosses the sea, but even on the coasts of Algeria it can be very perceptible.

Rainfall

The rainfall differs much from place to place, and is notably variable from year to year, particularly in autumn; drought is a serious menace.

A prominent feature is the difference between west and east coasts; the mountains that rise steeply from the east of the Adriatic are among the rainiest regions of the continent; Crkvice, 3,610 feet above the sea, overlooking the Bocche di Kotor (Cattaro), has the heaviest rainfall on the mainland, 182 inches, while the opposite shore of the Adriatic has only 25; of coastal stations Durrës (Durazzo) has 43 inches, Bari only 22. The east coasts of Greece have about half as much rain as

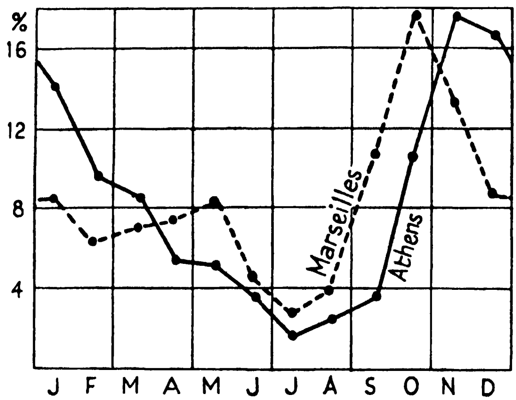


FIG. 115. Mean monthly precipitation, percentage of yearly total.

the west, and the east of Spain is very much drier than the Portuguese coast, where the Serra da Estrella was formerly thought to be the rainiest part of Europe.

East from the Azores, over the Mediterranean, Black Sea, Caspian Sea, and as far as Lake Balkhash and Afghanistan, most of the rain falls in the winter half-year. In general the rains begin in the middle of September and set in with full vigour in October, but with considerable local differences. In the Mediterranean region the simplest régime is in the south and east where early winter is the rainiest period, December or November being the rainiest month; summer is almost rainless, one or more months having hardly even an occasional thunderstorm. Such are the conditions at Athens (Fig. 115), where in 46 years July was rainless 13 times and August 17. Sicily has a similar régime. The dry season is shorter towards the north and west—Tripoli has 7 almost dry months, Malta and Sicily 3–4, Naples and Rome 2, the French Riviera 1.

Most of Mediterranean Europe, except the south of Spain Italy and Greece, has two maxima in the year, the larger in autumn, which is essentially the rainy season, and a secondary in spring. Summer is the dry season, but no month is rainless, though July is almost so in many regions. The line separating these two régimes cuts off the south-east of Spain, runs between Sardinia and Corsica, crosses Italy a little north of Sicily, and the Balkan Peninsula from Corfu to Euboea.

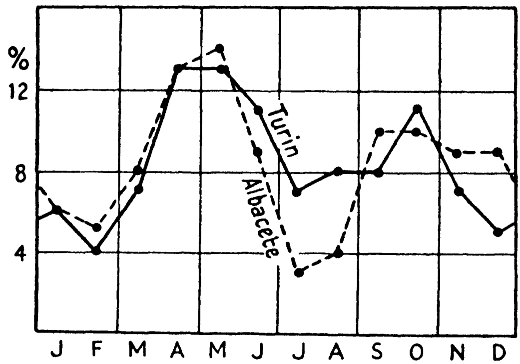


FIG. 116. Mean monthly precipitation, percentage of yearly total.

The Spanish Meseta has another régime, again with two maxima, in late spring and autumn; north of the Tagus the spring maximum is the higher, and the summer half-year has more rain than the winter half (Albacete, Fig. 116), a régime which distinguishes it from the true Mediterranean type; the rainfall maximum in May is associated with a maximum of showers and thunderstorm activity. A similar régime, but with least rain in winter, is found in the Po plains (Turin, Fig. 116), the Maritsa valley in Bulgaria, and the interior of Georgia. Much of the summer rain (which is considerable in these districts) falls in shallow, sluggish, thermal depressions, many of them giving cloud and rain but only light winds.

The precipitation differs from that of the rest of Europe not only in its periodicity but also in the small number of rain-days. St. Malo in Brittany and Cannes on the Riviera have about the same mean annual total, but at St. Malo it is distributed over 189 days, at Cannes only 66. On the dry south-east coast of Spain Malaga has 49 rain-days, Cartagena only 43; in most of the Mediterranean the number is larger, 80 to

110 days in Italy (but only 72 at Brindisi), but even the highest figures are less than in most of the rest of Europe. The dry summer is one cause, but the rainy months of winter also have fewer rain-days than in the north; thus at Cannes the rainiest month, October, has 5·4 inches of rain, but it all falls on 7 days; the rainiest month at Naples is again October, with 5 inches but only 11 rain-days. We may compare Portland, England, with 4 inches but 17 rain-days in the same month. The rainfall in the winter in much of the region is much larger than in most of north Europe, but it falls more heavily, on fewer days and in fewer hours on those days; records of over 5 inches in a day, often with thunder, are not uncommon in the drier areas:

Records of Heavy Rainfall in 24 hours

Gibraltar	7·8 in. (Jan.)	Tripoli	5·1 in. (Nov.)
Marseilles	8·7 ,, (Oct.)	Haifa	7·2 ,, (Dec.)
Malta	11·6 ,, (Oct.)	Port Said	2·3 ,, (Feb.)

Such downpours, most frequent on the mountains, are an outstanding feature, one result of which is destructive floods, and the rivers, whose beds are merely dry sandbanks in the summer, may be filled in a few hours with roaring torrents. The steep mountain-slopes which improvident man has deforested are swept bare of their soil, and the white limestone is exposed, to glare in the dazzling sunshine which soon follows the rain. Most of the rain is at the cold fronts of depressions, and therefore falls rather in heavy showers than in long spells. But the heavy and often lengthy rains from moist siroccos in front of depressions are a feature of the Adriatic and the north-west Mediterranean, particularly on elevated coasts. Light drizzle is much less common than in most of Europe.

Thunder is of only moderate frequency; on the lands in the north and especially in the north-west it is fairly common in summer, when the heat causes vigorous convection, particularly in the Po plains, but on the sea, and the south and east coasts, it is rare except in autumn and winter at cold fronts. The mean annual number of days with thunder is about 15 on the coasts of the central Mediterranean, 20 on the north-west and 12 in the east.

Snow. Snow is rarely seen on the coasts. The north of the Adriatic and Aegean have most, about 6 days a year; the

coasts of the Gulfs of Lions and Genoa have 2 or 3 days, the west and south of Italy and Greece 1 or 2 days, the east of Greece 4 days, the islands and the African coast rarely any. But the frequency and the amount increase rapidly inland, particularly on mountains; in the plains of Lombardy, the north of the Meseta of Spain, and the interior of Anatolia, snow may be deep enough in December and January to hold up rail traffic, and this may happen also on the Apennines. But though many ranges are snow-covered in winter above 4,000 feet, the High Atlas and the Sierra Nevada of Spain alone retain a few patches all the year.

Precipitation and Plant-life. The summer drought, which is liable to be abnormally prolonged and intense, necessitates various devices in the plant-world for resisting excessive evaporation; thickened stems, thick bark, thorns, waxy coatings, small leaves, growths of hair, are characteristic. Succulents have found a congenial habitat. Summer is the resting time, not winter as in the rest of Europe.

'At the end of April showers become rarer, the sun pours down his fiery rays more vertically, the ground hardens, and cracks open and the soil powders to dust. Plants die, and grey and yellow tints take the place of the glorious blooms, which are now withered and fallen to the ground. August and September are the months with fewest flowers, the landscape is parched and lifeless, only the cicada is heard among the grey olive trees. The land which in December gloried in a green carpet of wheat fields now recalls a desolate sunburnt steppe over which hangs the calina, the peculiar heat-haze of the south. So Nature continues to sleep till the rains of autumn rouse her to new life and the seeds spring up which were scattered by the short-lived annuals, grasses, and shrubs before they died. The woody bushes put forth new shoots, and the sap begins to circulate in the tubers and bulbs which have been protected in the hot ground by their numerous coats.'

In the south Mediterranean plant-life continues active in winter, but in the north the cold in mid-winter checks growth, and an outburst of energy is called forth by spring. Luxuriant vegetation requires heat and moisture at the same time, but the Mediterranean hot season is rainless and most growth has to occur in a comparatively cool season. The natural vegetation is forest, but the trees are of less noble proportions

than in both Central Europe to the north and the tropics to the south, where the growing season is the hottest time of the year. The typical Mediterranean trees are evergreen, so that they can continue their slow growth even in summer whenever there may chance to be water, and they commonly have very long roots which enable them to tap great depths. To the absence of rain in the hot season the region owes its healthiness and considerable immunity from endemic diseases. But in districts with much standing water, such as the deltas of the rivers, the coastal marshes, and lake basins, mosquitoes found an excellent breeding-ground, and malaria was so rampant that many such spots had to be deserted. Recent remedial measures have succeeded in almost eradicating malaria.

Sunshine. Visibility. Humidity

The week-long palls of cloud of the north of Europe are almost unknown in the south. Montpellier has 2,316 hours of sunshine a year, twice as much as the north of Great Britain, and the south Mediterranean still more:

	Mean Sunshine, hours		
	Month with most	*Month with least*	*Year*
Kew	June, 203	Dec., 38	1,466
Berlin	„ 247	„ 34	1,614
Rome	July, 348	„ 107	2,362
Athens	„ 362	„ 125	2,737

Visibility. In the middle and south of the region ordinary fog is much less frequent than in north and Central Europe but dust as thick as fog is sometimes carried from the desert over the south coasts, notably in Tripoli, and in smaller quantity often impairs visibility elsewhere; this haze is the calina of the Aegean. Particles of sea-salt are another cause of haze; and the winter storms may give thick weather. However, visibility is good generally, but with considerable local variations depending on the surfaces over which the winds have passed; near towns industrial haze is a factor (table, p. 371).

Humidity. The air is much drier than in north Europe. Curiously enough, some of the districts with most rainfall have the lowest relative humidity. Genoa, with an annual rainfall of 52 inches, has a mean humidity of only 62 per cent., and occa-

sionally readings down to 8 per cent. are recorded. Similarly dry air is a feature of all the Italian and French Riviera, and is partly a result of the descending currents from the mountains to windward. The mean monthly humidity at Montpellier ranges from 55 per cent. in July to 82 per cent. in January, at Rome from 55 per cent. in July to 74 per cent. in December, at Athens (mean of observations at 0800, 1400, 2100) from 48

MEAN PERCENTAGE FREQUENCIES OF RANGE OF VISIBILITY IN WINTER (DEC.–FEB.) AND SUMMER (JUNE–AUG.)

			0–1,100 yds.	*1,100 yds.– 2·5 miles*	*2·5–12·5 miles*	*More than 12·5 miles*
Marseilles:	winter,	0700	2	3	63	32
		1300	0	2	58	40
	summer,	0700	0	1	47	53
		1300	0	< 1	30	71
Split:	winter,	0700	0	1	22	77
		1300	0	< 1	16	84
	summer,	0700	0	1	27	73
		1300	0	< 1	4	96
Athens:	winter,	0800	1	6	84	9
		1400	1	6	84	11
	summer,	0800	1	6	80	13
		1400	0	2	85	14
Algiers:	winter,	0700	0	1	48	52
		1300	0	< 1	22	77
	summer,	0700	< 1	1	30	70
		1300	0	< 1	15	86
Malta:	winter,	0700	< 1	< 1	8	91
		1300	0	< 1	9	91
	summer,	0700	< 1	0	12	89
		1300	0	0	4	96

per cent. in August to 74 per cent. in December. In parts of Greece readings as low as 5 per cent. are sometimes recorded.

CLIMATIC REGIONS

Iberia (Fig. 117) is large and compact enough to have continental features. The winter cold engenders high atmospheric pressure (Fig. 118) with outblowing winds (the cold Norte of east Spain), but in the heat of summer pressure is low and the air moves inward. Thus the winds are monsoonal; only the winds, however, for summer is a season of bright sunshine and almost unbroken drought; the air is heated when it passes from the sea to the hot land and its vapour-capacity is increased; it rises but is carried away in the outflow aloft before

it can be cooled to dew-point. The S. or SE. wind of early summer on the south-east coast is at times a dry, hot, dusty, and unpleasant scirocco, and is then known as leveche (p. 359). The llevante (p. 359) is a wind of spring and autumn in the same district but of very different quality, being a polar current, NE. or N., of cold air, often with heavy rain, and snow on the mountains.

Region 1, *the Meseta.* In spite of the altitude New Castile has a higher mean temperature in summer than the coasts; the sunshine (2,909 hours a year at Madrid) is strong and the days very hot, but at sunset temperature falls fast; the mean diurnal range in July is about 30°, nearly twice the range at Lisbon (data on p. 363). Winter, however, is much colder than on the coasts; long spells of frost with temperatures as low as 15° are not uncommon, skating is sometimes to be had at Madrid, and traffic is seriously impeded by snow in the mountains and on the plains of Old Castile. Many winter nights, and even days, are piercingly cold everywhere.

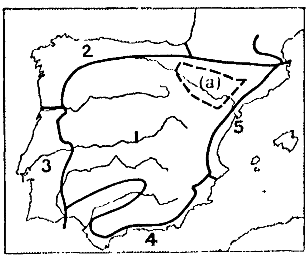


FIG. 117. Major climatic regions of Iberia.

The summer drought is broken only by an occasional thunderstorm; the heat is intense, evaporation vigorous, and the vegetation is dried up. Failing irrigation, the landscape is semi-desert, brown and grey; dust is everywhere, the parched ground is deep in dust and the dry air is hazy with the particles swept up by the strong wind. This haze, calina, is due to shimmering as well as dust, and its dismal grey often obscures the view in the south Mediterranean lands. In winter and spring surface fog of the inversion type is liable to occur on calm nights under a clear sky, but it usually clears by midday; otherwise visibility is good. The west and north coasts get sea-fog in summer with light winds from the cool Portuguese Current.

The high pressures of winter check the ingress of storms and February has little more rain than July; spring and autumn have most, and the spring rain, together with the strong winds and extreme temperatures, favours steppe vegetation. Thunderstorms with heavy downpours occur in spring and, much

less often, in summer. In general, the Meseta has an extreme and harsh climate in comparison with the more favoured coasts.

The Ebro plains, 1(a), are low, but with their more northerly position have about the same mean temperature as Madrid.

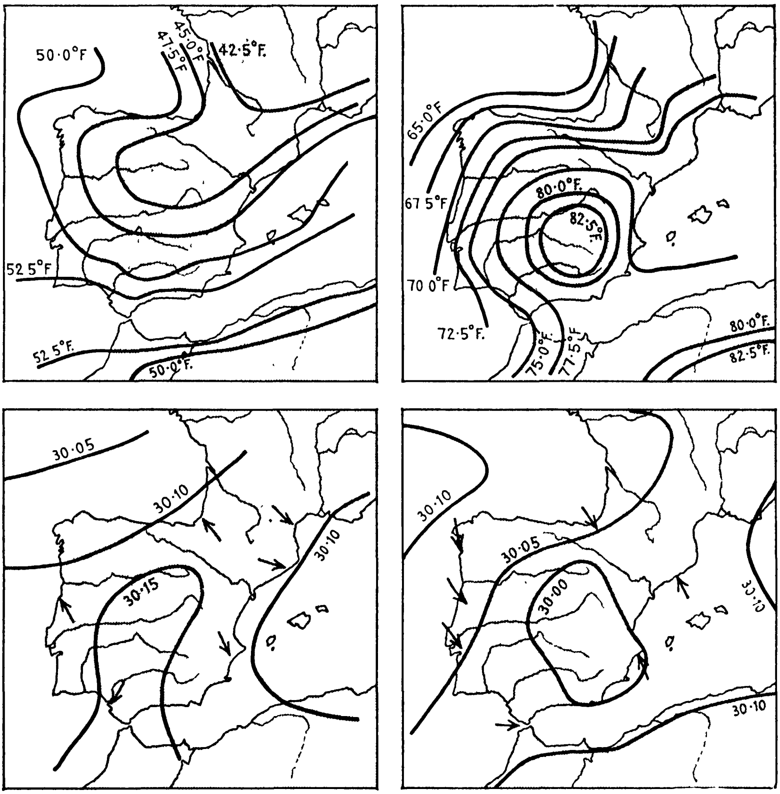


FIG. 118. Mean isotherms and isobars.

Here too the climate is extreme, the precipitation small (under 15 inches) and unreliable, with long droughts and some torrential downpours, and the natural vegetation is of steppe character.

2. The north coast has a west-European, rather than a Mediterranean, coastal climate, with warm winters, small range of temperature, and rainfall exceeding 50 inches in much of the region; it is heaviest under the westerlies of winter, but considerable in summer also.

3. The west coast has the oceanic variety of Mediterranean climate—cool summers, mild winters, small range of temperature, abundant sunshine (2,741 hours a year at Lisbon); rain in the winter half-year, very little in summer, but with the damper air the summer aridity is less prominent than in the interior and east of the peninsula.

4. The narrow south and south-east littoral, sheltered by the Sierra Nevada, is noted for its very hot and sunny summers. The rainfall (most in November) is scanty, but streams from the melting snows on the mountains provide irrigation. The most tropical fruits grown in Europe are cultivated, including the date palm and the banana. The plain of Andalusia has the hottest summers of Iberia, and indeed of Europe; at Seville the mean temperature in August is 83°, with maxima in an average year up to 116°, a figure approaching the records of the Sahara. Sunshine is notably abundant all the year, and the sky is almost cloudless in summer. But the rainfall is scanty and unreliable; much of it falls in very heavy showers, and long droughts are a serious affliction.

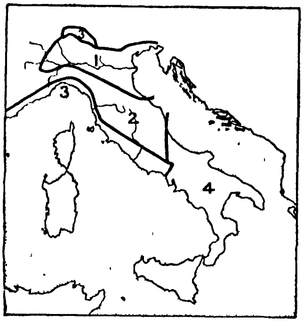


FIG. 119. Major climatic regions.

5 resembles 4, but is cooler throughout the year, mostly so in autumn and winter.

Italy (Fig 119). 1. These plains are more akin to Central Europe than the Mediterranean. The summers are almost as hot as in Sicily, but the winters are cold, much colder than on the Riviera beyond the mountains, for the plains are often covered with cold damp air, with pronounced inversion of temperature; the sunshine (1,618 hours a year at Turin) is little more than at Berlin. The Italian lakes have milder winters, lemon-groves and olive-trees suggesting a Mediterranean climate, but the precipitation (67 inches at Lugano) is too high and the summers too rainy for a Mediterranean land. When we cross the Alps from the north we seem to enter a new region in these mild sunny valleys, but to return to the Central Euro-

pean winter at Milan, where snow often lies for days, and skating is sometimes possible. Piacenza has the same mean January temperature as Berlin, lower than the south of the Lofoten Islands. Even the rapid River Po and the lagoons round Venice have been frozen over, but not within living memory. Venice is somewhat milder than the plains to the west, thanks to the influence of the sea. The prevailing wind in winter blows down the Po to the Adriatic, in summer upstream.

The rainfall is about 30 inches a year on the plain (only 20 inches in some districts) and about 40 inches along the foot of the surrounding mountains. It is more evenly distributed over the year than in true Mediterranean lands, and, in opposition to the régime of the latter, the summer half-year has more rain than the winter. The rainiest months are in autumn and spring, the driest are January and February. The summer rain and abundant irrigation from the mountain torrents provide for large crops of maize and rice, grown only here in Italy.

2. The north Apennines and the highlands of Tuscany carry the Central European climate south. Most rain falls in the winter half-year, but summer is not rainless; the mean annual total exceeds 50 inches on the heights. Frost is to be expected even on the coasts of north Italy every winter, and the mountains are sometimes buried deep in snow for some months even in the south.

3. The Riviera.

4. South Italy has a very dry and hot summer even in the mountains; frost is rare in winter near the sea. The climate is typically Mediterranean, with most rain in winter (rainiest month November). Sicily is favoured in its very warm winters, frost being almost unknown on the littoral. The summers are hot and very sunny (2,358 hours of sunshine a year at Messina), the air dry. The rainfall is small and the rainy season short, so that the climate may perhaps be considered the most Mediterranean in Italy.

Throughout peninsular Italy the varied topography gives local climates with many differences.

The Balkan Peninsula (Fig. 120). Even more than in Italy the local climates of adjacent districts differ much according to the direct effect of altitude, shelter by neighbouring hills, and access for maritime influences. In winter the more enclosed

basins, particularly those situated at some altitude, hold lakes of very cold air which has gravitated from the surrounding ranges; these same basins (particularly those at low altitudes) have very hot summer days, especially when the livas, a wind of föhn type, blows from the mountains.

1. The west coast has a Mediterranean climate with very rainy but mild winters, subject to visitations of the bora.

2 has a very favourable Mediterranean climate, warmer than the Dalmatian coast, especially in winter when the mean temperature is as much as 10° higher; moreover there is no bora.

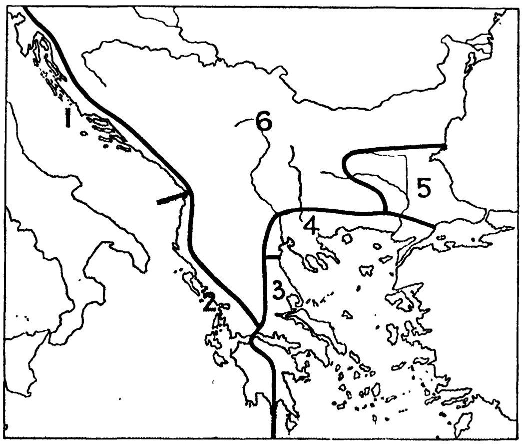


FIG. 120. Major climatic regions.

The rainfall, 30 to 40 inches a year, has a single maximum in winter; summer is almost but not quite rainless. Zante has one of the highest sunshine records in Greece, 3,107 hours.

3 differs from 2 in being an east coast. The rainfall is considerably less, 20 to 30 inches a year, and the land is dry and dusty through the long summer months; in comparison west Greece is a land of running waters. The winters are much cooler—mean January temperature at Athens 47°, at Zante 53°—and in enclosed basins at a distance from the sea keen frosts occur, zero readings having been recorded in Thessaly. But on the coasts of the Peloponnese frost is rare. Summer days are very hot and dry at places beyond reach of the sea-breeze such as Sparta, where the July mean is 82°, and from June to September the temperature rises well over 90° on most days, and may exceed 100°.

4. The north coast of the Aegean has a Mediterranean climate, and the olive is a common tree. But the colder winters and the appreciable rainfall in summer mark it as a separate region. An anticyclone often covers the Balkans in winter and a cold N. wind blows down the valleys to the coast. Under such conditions a reading of 14° F. was once observed at Salonica, and much of the inner gulf had a thin coating of ice. On most January nights the mercury falls nearly to freezing-point, and in Macedonia and Thrace even the day maximum may occasionally be below 32°. A good deal of snow falls with NE. winds in winter.

5 has a transition climate between the Mediterranean and the steppes. Most of the rain is in winter, as in the Mediterranean lands, but bleak N. winds from the steppes of Russia bring low temperatures, precluding the typical Mediterranean flora; the olive does not flourish. The northern plains are coldest; Istanbul is somewhat warmer thanks to its peninsular position, but a reading of 17° has been recorded, and snow falls on the average on 18 days a year. The Bosporus has been covered with ice so that the passage from Europe to Asia could be made on foot. The ice, however, had probably drifted from the coasts of the Black Sea and, being compacted in the narrow channel by the current, had frozen into a solid covering.

6 must be classed with Central Europe, having rain all the year, with maxima in May and June and October like south Hungary. The winters are cold for the latitude. The Mediterranean vegetation of the coasts of the Aegean is replaced by the forest trees of Central Europe. The lower Danube lands have some distinctive winds; the Crivetz blows from NE. in spring and autumn and brings very variable weather—hot in the hotter months, cold in the colder, sometimes dry, sometimes rainy or snowy; the Austru is essentially a winter wind from W., bringing dry, clear, and often very cold, weather; the Kossava, a cold dry wind, blows in winter from SE. down the lower Morava; it is noted for its coarse dust which darkens the atmosphere and may form appreciable deposits. The higher mountains, even far south in the Peloponnese, have bleak winters, with much snow which continues to lie in some places above 5,000 feet till June.

CLIMATIC MEANS

TEMPERATURE (°F.)

North-west Europe

	Alt. feet	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*	*Range*
British Isles															
Valentia	30	45	*44*	45	47	52	56	59	**59**	56	52	47	45	51	15
Dublin	155	*41*	41	42	45	51	55	**59**	58	54	49	43	41	48	18
Scilly	163	47	*45*	47	48	52	57	61	**61**	59	54	49	47	52	17
Portsmouth . . .	15	*41*	41	44	48	55	59	63	**63**	59	53	46	43	51	22
Dungeness . . .	20	41	*41*	43	46	52	57	62	**62**	59	53	46	42	50	21
London (Kew) . .	18	*41*	41	43	47	55	59	**63**	62	57	51	44	41	50	22
Oxford	212	*39*	39	42	46	53	58	**61**	61	56	49	43	40	49	22
Cambridge . . .	41	*39*	40	42	46	53	58	**62**	61	57	50	43	40	49	23
Holyhead . . .	26	44	*43*	44	46	51	55	59	**59**	57	53	47	45	50	16
Buxton	1,007	*36*	37	39	43	49	54	**57**	57	53	47	41	37	46	21
York	57	*39*	40	42	46	53	57	**61**	60	56	50	43	40	49	22
Leith	18	*39*	39	41	45	50	56	**59**	58	55	49	43	40	48	20
Fort William (1884–1903).	171	39	*39*	40	45	50	55	**57**	56	53	47	44	40	47	18
Ben Nevis (1884–1903) .	4,406	24	*24*	24	28	33	40	**41**	40	38	31	29	25	31	17
Braemar . . .	1,120	*34*	34	36	41	46	53	**55**	54	50	43	38	35	43	21
Aberdeen . . .	37	39	*39*	40	43	48	53	**57**	56	53	48	42	40	47	18
Orkney (Deerness) . .	160	40	*39*	40	42	46	50	54	**54**	51	46	43	41	45	15

North-west Europe (continued)

	Alt. feet	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*	*Range*
France															
Biarritz	115	*46*	48	50	54	59	64	68	**69**	65	59	51	47	57	23
Pic du Midi . . .	9,383	*18*	18	19	23	29	37	43	**43**	38	31	24	20	29	26
Bordeaux . . .	246	*41*	43	47	53	58	64	**68**	68	64	55	47	41	54	27
Nantes	131	*40*	43	45	50	57	61	**65**	63	60	52	46	41	52	25
Paris	164	*37*	39	43	49	56	62	**65**	64	59	50	43	38	50	28
Lille	66	*36*	38	42	48	54	60	**63**	63	59	51	42	37	49	27
Holland, Belgium															
Utrecht	7	*35*	36	41	46	54	59	**62**	61	57	49	42	37	48	27
Groningen . . .	7	*34*	35	39	45	53	59	**61**	61	57	48	41	37	48	27
Brussels (Uccle) . .	328	*36*	38	42	48	56	61	**64**	63	59	51	42	38	50	28
Germany															
Emden	26	*34*	35	38	45	53	59	**62**	61	56	49	40	36	47	28
Hamburg . . .	66	*33*	34	38	45	54	60	**63**	62	56	48	39	34	47	30
Norway															
Skudenes . . .	23	36	*35*	36	41	48	54	57	**57**	54	47	41	38	45	22
Bergen	72	*34*	34	36	42	49	55	**58**	57	52	45	39	36	45	24
Lärdal	10	*29*	30	34	42	51	58	**61**	58	51	42	35	31	43	32
Ona	39	37	*36*	37	40	44	50	54	**54**	52	46	41	38	44	18
Kristiansund . . .	49	35	*34*	35	40	46	52	56	**56**	51	45	38	35	43	22
Trondheim . . .	131	*27*	28	31	38	46	54	**57**	55	49	41	33	28	41	30
Fanaraken (Jotunheim) .	6,765	*9*	10	13	17	25	32	**38**	36	29	22	17	13	21	29
Röros	2,067	*13*	14	19	29	39	49	**52**	50	42	32	22	14	31	39
Skomvaer . . .	52	34	*33*	33	36	41	46	50	**51**	47	42	38	35	41	18
Tromsö	148	26	*25*	26	32	39	47	**52**	51	44	36	30	27	36	27
Vardö	33	22	*21*	23	29	35	42	48	**48**	43	35	28	24	33	27

TEMPERATURE (°F.) (*continued*)

North-west Europe (continued)

	Alt. feet	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year	Range
Denmark															
Fanö	16	*33*	33	36	42	51	57	**60**	60	55	48	40	36	46	27
							Central Europe								
France															
Clermont-Ferrand	1,280	*35*	39	43	50	56	62	**66**	65	59	51	42	36	50	31
Puy de Dôme	4,823	*28*	29	30	35	41	48	**52**	52	48	40	34	29	39	24
Lyon	574	*35*	39	44	52	58	64	**68**	67	61	52	42	35	51	33
Briançon	4,259	*28*	30	34	42	50	57	**62**	61	55	45	35	30	44	34
Strasbourg	456	36	36	42	49	59	63	**67**	65	59	50	40	*35*	50	32
Scandinavia															
Oslo	82	*24*	25	31	41	51	60	**63**	60	52	42	33	26	42	39
Finse	4,022	17	*16*	18	25	33	41	**46**	45	39	30	22	17	29	30
Röros	2,067	*13*	14	19	29	39	49	**52**	50	42	32	22	14	31	39
Göteborg	52	31	*31*	34	42	51	59	**62**	61	55	46	39	33	45	31
Karlstad	174	*26*	26	30	39	49	59	**63**	60	53	43	34	28	42	37
Stockholm	144	27	*26*	30	38	48	57	**62**	59	53	43	35	29	42	36
Hernösand	30	*21*	21	26	34	43	54	**59**	57	49	40	30	23	38	38
Haparanda	30	12	*11*	18	30	41	53	**60**	55	46	35	25	16	33	49
Copenhagen	16	*31*	31	35	42	52	60	**63**	61	55	47	39	34	46	32
Germany, Poland															
Köln	184	*36*	38	42	49	57	62	**65**	64	59	51	42	37	50	29
Hanover	187	*33*	34	39	46	55	61	**63**	61	56	48	40	35	48	30
Szczecin (Stettin)	85	*31*	32	37	45	55	62	**65**	63	57	48	38	33	47	34

Central Europe (continued)

	Alt. feet	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year	Range
Germany, Poland (cont.)															
Berlin	187	*31*	32	38	46	56	61	**64**	62	56	47	38	33	47	33
Dresden	367	*32*	34	40	47	56	62	**65**	64	58	49	40	34	48	33
Wroclaw (Breslau)	482	*30*	31	37	47	56	63	**66**	64	58	49	38	32	48	36
Poznan (Posen)	217	*29*	31	37	46	56	62	**66**	64	57	47	37	32	47	37
Warsaw (Warszawa)	436	*26*	28	35	46	57	63	**66**	64	56	46	36	29	46	40
Frankfurt a/M.	338	*33*	36	42	49	58	63	**66**	64	58	49	40	35	49	33
Mannheim	328	*34*	36	42	50	58	64	**67**	65	59	50	41	36	50	33
Stuttgart	876	*34*	36	42	49	57	63	**66**	65	59	50	41	35	50	32
Nürnberg	1,014	*31*	33	39	47	56	62	**65**	63	57	47	38	33	48	34
Munich	1,739	*28*	31	37	45	54	60	**63**	62	56	46	36	30	46	35
Zugspitze	9,719	*12*	12	14	19	27	31	35	**35**	32	25	19	14	23	23
Switzerland															
Basel	1,040	*31*	34	40	48	56	62	**65**	63	58	48	39	33	48	34
Geneva	1,329	*33*	36	41	49	56	63	**67**	65	59	49	41	35	49	34
Lucerne	1,634	*31*	33	39	47	55	61	**65**	63	57	47	39	32	47	34
Altdorf	1,480	*32*	36	41	49	55	61	**64**	63	58	49	41	33	49	32
Andermatt	4,741	*20*	23	28	36	43	49	**53**	52	47	39	30	22	37	33
St. Gotthard	6,877	*18*	19	21	28	34	41	**46**	46	41	32	25	19	31	28
Jungfraujoch	11,739	*6*	8	8	12	17	27	**29**	29	26	18	16	5	17	23
Sargans	1,663	*30*	34	40	48	55	61	**64**	62	58	49	40	31	48	34
Säntis	8,202	16	*16*	18	23	31	37	**41**	41	37	30	23	18	28	25
Davos	5,121	*19*	22	28	36	45	51	**54**	52	47	38	30	22	37	35
Bevers	5,610	*14*	19	24	33	42	49	**53**	51	46	36	26	16	34	39
Middle Danube States															
Innsbruck	1,970	*26*	31	39	48	55	62	**65**	63	57	49	38	29	47	39
Klagenfurt	1,444	*25*	27	38	48	57	64	**68**	65	58	47	38	28	47	43

TEMPERATURE (°F.) (*continued*)

Central Europe (continued)

	Alt. feet	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year	Range
Middle Danube States (cont.)															
Graz	1,129	*29*	31	39	49	58	64	**67**	65	59	49	40	32	49	38
Vienna	663	*28*	32	39	49	58	64	**67**	66	59	49	38	31	48	39
Zagreb (Agram)	535	*32*	36	44	53	61	67	**71**	69	62	53	42	35	52	39
Budapest	427	*30*	33	42	53	62	68	**71**	70	62	52	40	33	51	41
Debrecen	423	*28*	31	41	51	61	66	**70**	68	60	50	39	32	50	42
Szeged	295	*31*	33	44	53	63	68	**72**	71	63	53	42	34	52	41
Lower Danube States															
Beograd (Belgrade)	453	*32*	33	43	54	63	68	**73**	71	64	55	45	35	53	41
Sofia	1,804	*29*	33	41	50	59	65	**69**	68	61	51	40	33	50	40
Skoplje (Üsküb)	804	*29*	34	45	53	62	69	**74**	72	66	57	43	34	53	45
Bucuresti (Bucharest)	276	*24*	30	40	51	62	68	**73**	72	63	53	40	30	51	49
Sulina	7	*31*	33	40	49	59	67	**71**	70	63	55	44	36	51	40

The Mediterranean Lands

	Alt. feet	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year	Range
Spain and Portugal															
Corunna	82	*49*	50	51	53	57	61	64	**65**	63	58	53	51	56	16
Lisbon	321	*51*	52	55	58	62	67	70	**71**	68	63	56	52	60	20
Gibraltar	90	*55*	56	57	60	65	69	73	**75**	72	66	60	56	64	20
Cartagena	43	*52*	54	56	62	65	72	77	**78**	74	67	60	53	64	26
Barcelona	136	*47*	49	51	56	62	69	74	**75**	69	62	54	49	60	28
Saragossa	673	*42*	47	51	56	64	70	**76**	75	69	58	49	42	58	34
Burgos	2,822	*36*	40	43	48	53	60	65	**66**	60	51	43	37	50	30
Madrid	2,148	41	44	48	54	62	70	**78**	77	68	57	47	*40*	57	38
Seville	98	*50*	54	58	63	69	76	82	**83**	77	67	58	51	65	33

The Mediterranean Lands (continued)

	Alt. feet	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year	Range
France															
Montpellier	115	41	44	48	55	61	68	73	72	65	57	48	42	56	32
Avignon	66	39	43	49	56	63	71	75	73	66	57	47	40	57	36
Marseilles	246	43	45	49	55	61	68	72	71	66	58	50	44	57	29
Nice (Éc. Nor.)	66	46	47	51	57	62	69	74	73	68	61	53	47	59	28
Italy															
Bolzano	666	34	39	47	55	62	69	73	71	65	54	44	36	54	39
Milan	482	35	40	47	56	65	73	77	76	68	55	45	36	56	42
Cremona	222	33	38	46	55	63	71	76	74	67	56	44	36	55	43
Genoa	177	46	47	51	57	63	70	75	75	70	62	53	47	60	29
Venice	82	37	41	47	54	64	71	75	74	67	57	47	40	56	38
Rome	208	45	47	51	57	64	71	76	75	69	62	53	47	60	31
Naples	489	47	48	51	57	64	70	75	75	71	63	55	49	60	28
Palermo	234	50	52	55	59	64	71	76	77	73	67	59	53	63	27
Balkan States															
Trieste	85	40	42	47	55	63	71	75	74	67	59	49	42	57	35
Split	420	45	46	51	58	65	73	78	77	70	62	53	47	60	33
Corfu	89	51	52	55	60	68	74	79	79	75	67	60	54	65	28
Athens	351	47	48	53	59	67	75	80	80	74	66	57	51	63	33
Salonica	129	42	45	50	57	67	74	80	78	72	63	52	46	61	38
Istanbul	164	41	40	45	53	61	69	74	74	68	62	54	45	57	34
Patras	131	50	51	54	61	68	75	80	80	74	67	60	53	65	30

PRECIPITATION (inches)

North-west Europe

	Alt. feet	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*
British Isles														
Valentia	30	5·5	5·2	4·5	3·7	*3·2*	3·2	3·8	4·8	4·1	5·6	5·5	**6·6**	55·7
Dublin	155	2·3	*1·8*	1·9	1·8	2·1	2·0	2·7	**3·2**	*1·9*	2·6	**2·8**	2·5	27·6
Plymouth	117	3·3	2·9	2·9	2·2	*2·1*	2·1	2·8	3·0	2·4	**3·9**	3·6	5·0	36·2
London (Kew)	18	1·8	1·5	1·7	*1·5*	1·7	2·1	2·2	2·2	1·9	**2·7**	2·2	2·3	23·8
Oxford	212	2·1	1·6	*1·6*	1·8	1·9	2·1	2·5	2·3	2·3	**2·7**	2·3	2·2	25·5
Nottingham	82	1·7	1·5	1·6	*1·3*	1·8	1·9	2·3	**2·4**	*1·6*	**2·4**	1·8	2·3	22·5
Buxton	1,007	4·5	3·8	4·1	*2·9*	3·1	3·2	3·9	4·4	3·2	4·9	4·7	**5·7**	48·4
York	57	1·8	*1·5*	1·7	1·6	2·0	2·1	**2·5**	2·5	*1·6*	**2·7**	2·1	2·2	24·3
Seathwaite	422	13·3	11·9	11·2	7·4	7·4	*6·5*	8·5	**11·6**	*9·9*	12·0	13·6	**16·3**	129·5
Edinburgh	227	1·7	1·6	1·9	*1·4*	2·0	1·9	2·7	**3·1**	*2·0*	**2·6**	2·1	2·2	25·0
Glasgow	85	3·3	2·9	2·7	*2·1*	2·6	2·5	3·1	**3·9**	*3·0*	3·4	3·6	**4·1**	37·2
Fort William (1891–1903)	171	8·7	6·9	7·2	4·2	*3·5*	3·5	4·6	6·9	**8·2**	7·9	*7·5*	**11·3**	80·4
Ben Nevis (1891–1903)	4,406	18·7	15·1	17·0	10·2	8·3	*7·8*	11·3	14·0	**16·9**	*14·8*	16·0	**21·2**	171·3
Nairn	82	2·0	1·8	1·9	*1·5*	1·8	1·8	**2·7**	2·4	2·2	2·4	2·4	2·2	24·9
France														
Bayonne	66	3·9	3·3	3·9	3·7	3·3	3·6	*2·5*	2·9	4·3	**5·5**	5·4	4·1	46·4
Bordeaux	246	2·4	2·0	2·2	2·5	2·6	2·8	*1·8*	1·9	2·6	3·3	**3·0**	2·5	30·0
Brest	217	3·3	2·6	2·0	2·1	*1·8*	2·0	2·0	2·2	2·8	**3·9**	3·6	3·4	31·6
Cherbourg	59	3·3	2·4	2·3	*1·8*	2·0	1·9	2·0	2·4	3·2	**4·8**	4·1	3·7	34·0
Paris	164	*1·4*	1·4	1·5	1·6	1·9	2·2	2·0	1·9	1·9	**2·3**	1·9	1·7	22·0
Lille	85	2·0	*1·6*	1·9	1·6	2·2	2·2	2·7	2·4	2·5	**3·1**	2·4	2·4	27·0

North-west Europe (continued)

	Alt. feet	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Holland, Belgium														
Utrecht	7	2·1	1·8	1·8	*1·7*	1·9	2·3	2·8	**3·2**	2·6	2·8	2·4	2·6	28·7
Groningen	7	1·9	1·6	1·7	*1·5*	1·8	2·4	2·8	**3·3**	2·6	2·6	2·3	2·1	27·2
Brussels (Uccle)	328	2·8	*2·0*	2·0	2·6	2·5	2·7	**3·4**	2·9	2·8	3·2	3·1	3·2	33·1
Germany														
Emden	26	2·3	*1·7*	1·9	1·8	1·9	2·6	3·0	**3·5**	2·5	2·7	2·3	2·6	28·8
Hamburg	66	2·1	1·9	2·0	*1·8*	2·1	2·7	**3·4**	3·2	2·5	2·6	2·1	2·5	28·9
Norway														
Bergen	72	8·8	7·1	6·1	4·4	4·6	*4·2*	5·6	7·7	**9·3**	9·2	8·7	8·7	84·4
Tromsö	148	4·3	4·4	3·1	2·3	*1·9*	2·2	2·2	2·8	**4·8**	4·6	4·4	3·8	40·7

Central Europe

	Alt. feet	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
France														
Clermont-Ferrand	1,280	*1·3*	1·3	1·7	2·0	2·7	**3·2**	2·4	2·6	2·8	2·2	1·7	1·3	25·4
Lyon	574	*1·4*	1·5	1·9	2·4	3·2	3·3	2·9	3·1	3·0	**3·8**	2·6	1·7	31·3
Annecy	1,470	*2·6*	2·7	3·5	3·9	4·8	5·2	4·4	4·8	4·7	**5·7**	4·3	3·3	50·6
Briançon	4,259	*1·3*	1·4	1·7	2·0	2·3	2·1	1·6	1·7	2·1	**3·0**	2·3	1·8	23·3
Chamonix	3,412	*2·3*	2·7	2·5	2·6	3·4	4·6	4·6	**5·1**	4·4	4·4	3·4	3·4	44·1
Besançon	1,020	2·8	*2·5*	3·0	3·2	3·8	4·1	3·7	3·6	4·2	**4·5**	3·5	3·1	42·5
Metz	581	1·9	*1·5*	1·8	1·7	2·0	2·7	**2·7**	2·4	2·2	2·6	2·2	2·2	25·8
Scandinavia														
Oslo	82	1·6	1·5	*1·5*	1·6	1·7	2·1	3·0	**3·5**	2·4	2·6	2·0	1·9	25·4
Röros	2,067	1·3	1·1	1·0	*0·8*	1·2	2·0	**2·6**	2·6	1·9	1·4	1·1	1·0	18·0
Stockholm	144	1·4	*1·3*	1·3	1·5	1·5	1·7	2·4	**2·9**	1·9	1·8	1·9	1·9	21·6

PRECIPITATION (inches) (*continued*)

Central Europe (continued)

	Alt. feet	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Scandinavia (cont.)														
Hernösand	30	1·4	1·4	1·7	1·3	1·9	1·9	2·4	3·1	2·5	2·8	2·2	2·0	24·7
Haparanda	30	1·4	1·1	1·0	1·1	1·1	1·3	2·1	2·5	2·4	2·3	2·0	1·5	20·0
Germany, Poland														
Köln	184	2·0	1·8	1·8	1·9	2·0	2·6	3·2	2·8	2·1	2·5	2·2	2·5	27·4
Hanover	187	1·7	1·6	2·0	1·6	2·0	2·7	3·2	2·7	1·9	1·9	1·7	1·8	25·2
Szczecin (Stettin)	85	1·7	1·2	1·4	1·5	1·7	2·0	3·0	2·5	1·8	1·7	1·5	1·9	21·9
Berlin	187	1·9	1·3	1·5	1·7	1·9	2·3	3·1	2·2	1·9	1·7	1·7	1·9	23·1
Dresden	367	1·7	1·4	1·7	1·9	2·5	3·0	3·7	2·8	2·3	1·9	1·6	1·9	26·4
Wroclaw (Breslau)	482	1·5	1·1	1·5	1·7	2·4	2·4	3·4	2·7	1·8	1·7	1·5	1·5	23·2
Poznan (Posen)	217	1·1	0·9	1·3	1·4	2·2	1·9	3·0	2·1	1·8	1·4	1·3	1·4	20·0
Warsaw (Warszawa)	436	1·3	1·1	1·3	1·5	2·0	2·6	3·1	2·9	1·8	1·7	1·5	1·4	22·2
Stuttgart	876	1·5	1·3	1·7	2·2	2·7	3·3	3·1	2·6	2·5	1·9	1·8	1·9	26·5
Freudenstadt	2,395	4·9	5·0	5·5	3·9	4·1	4·8	5·0	4·3	4·0	4·4	5·0	6·2	58·0
Nürnberg	1,014	1·5	1·2	1·3	1·7	2·2	2·5	3·1	3·1	2·1	2·1	1·9	1·7	24·4
Munich	1,739	1·7	1·4	1·9	2·7	3·7	4·6	4·7	4·2	3·2	2·2	1·9	1·9	34·1
Switzerland														
Basel	1,040	1·6	1·6	2·1	2·6	3·2	3·9	3·5	3·4	3·1	2·9	2·3	2·0	32·2
Geneva	1,329	1·9	2·0	2·5	2·7	3·0	3·1	3·1	3·8	3·3	3·9	3·1	2·7	35·0
Lucerne	1,634	1·9	1·9	2·6	3·5	4·5	5·8	6·0	5·6	4·2	3·5	2·4	2·3	44·1
Altdorf	1,496	2·5	2·4	3·0	3·8	4·2	5·4	6·1	5·8	4·2	4·2	3·2	3·2	48·0
St. Gotthard	6,877	6·1	5·5	7·8	8·1	8·2	7·0	7·4	7·7	8·1	9·8	8·2	7·4	91·3
Sion	1,801	1·7	1·7	1·8	1·5	1·6	1·8	2·1	2·6	1·9	2·3	2·0	2·4	23·2
Sargans	1,663	3·0	2·8	3·3	3·8	4·4	5·5	6·7	6·1	4·8	4·3	3·1	3·4	51·0

Central Europe (continued)

	Alt. feet	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Switzerland (cont.)														
Säntis	8,202	9·1	7·1	7·5	9·9	8·8	11·0	12·1	11·3	8·8	7·6	7·1	9·4	109·7
Davos	5,121	2·3	2·1	2·1	2·4	2·8	4·2	5·3	5·2	3·6	2·8	2·4	2·6	37·8
Bevers	5,610	1·5	1·4	2·0	2·3	2·8	3·4	4·2	4·3	3·6	3·5	2·7	2·1	33·7
Middle Danube States														
Innsbruck	1,970	1·6	1·6	2·0	2·3	2·8	4·0	5·2	4·6	3·4	2·4	1·6	2·1	33·6
Klagenfurt	1,444	1·4	1·6	2·1	3·7	3·6	4·8	3·8	5·3	4·5	4·2	3·5	2·0	40·5
Graz	1,129	1·1	1·2	1·5	2·8	3·3	5·2	4·9	4·4	4·1	3·4	2·4	1·6	35·9
Vienna	663	1·5	1·3	1·8	2·1	2·8	2·8	3·1	2·7	2·0	1·9	1·8	1·8	25·6
Zagreb (Agram)	535	1·8	1·9	2·2	2·8	3·1	3·9	3·2	3·2	3·4	3·9	3·1	2·4	34·9
Budapest	427	1·5	1·3	1·8	2·3	2·7	2·9	2·1	1·9	2·1	2·3	2·1	2·0	25·0
Debrecen	423	1·3	1·1	1·4	1·9	2·4	3·0	2·7	2·3	1·9	2·3	2·0	1·8	24·2
Lower Danube States														
Beograd (Belgrade)	453	1·6	1·3	1·6	2·2	2·6	2·8	1·9	2·5	1·7	2·7	1·8	1·9	24·6
Skoplje (Üsküb)	804	1·4	1·2	0·7	1·7	2·2	2·2	1·4	1·4	1·2	2·0	1·5	1·9	19·2
Sofia	1,804	1·1	1·3	1·6	2·1	3·3	3·2	2·7	2·1	2·2	2·2	2·0	1·1	25·2
Bucuresti (Bucharest)	276	1·3	1·3	1·6	2·1	2·2	4·0	2·2	1·8	1·6	1·7	1·7	1·7	23·2
Braila	98	0·9	0·8	1·3	1·2	1·7	2·4	1·8	1·4	1·3	1·3	0·9	0·9	16·2

The Mediterranean Lands

	Alt. feet	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Spain and Portugal														
Corunna	82	3·2	3·1	3·2	2·5	2·2	1·4	0·9	1·2	2·2	3·5	4·2	4·4	32·0
Lisbon	321	3·3	3·2	3·1	2·4	1·7	0·7	0·2	0·2	1·4	3·1	4·2	3·6	27·1
Gibraltar	90	4·6	4·5	4·7	2·7	1·6	0·5	0	0·1	1·3	3·3	6·4	5·4	35·1
Cartagena	43	1·8	1·4	1·6	1·1	1·0	0·8	0·1	0·2	1·4	1·7	1·9	2·0	15·0
Barcelona	136	1·4	1·5	1·8	1·9	1·7	1·5	1·0	1·3	3·0	3·1	1·8	1·4	21·4
Saragossa	673	0·7	0·8	0·9	1·1	1·5	1·1	0·6	0·6	0·9	1·3	1·2	0·8	11·5
Burgos	2,822	1·7	1·9	2·0	2·3	2·6	2·1	0·8	0·7	1·8	2·0	2·1	1·7	21·7

PRECIPITATION (inches) (*continued*)

The Mediterranean Lands (continued)

	Alt. feet	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*
Spain and Portugal (cont.)														
Madrid	2,148	1·3	*1·3*	1·6	**1·7**	1·7	1·3	*0·4*	0·6	1·5	1·8	**1·9**	1·4	16·5
Seville	98	2·5	*1·8*	**2·6**	1·8	1·6	0·5	*0*	0·1	0·7	2·4	**2·8**	2·7	19·5
France														
Montpellier	95	3·1	2·7	2·4	*2·3*	**2·8**	1·8	*0·9*	2·0	3·0	**4·1**	3·4	2·4	30·9
Avignon	66	1·5	*1·5*	1·6	2·0	**2·4**	2·0	*1·1*	2·0	2·9	**3·5**	2·6	1·8	25·4
Marseilles	246	1·9	*1·4*	1·6	1·7	**1·9**	1·0	*0·6*	0·9	2·4	**4·0**	3·1	2·0	22·5
Nice (Éc. Nor.)	59	2·5	*2·2*	**2·7**	2·2	2·4	1·6	*0·6*	0·9	2·4	**5·8**	4·4	3·1	30·9
Italy														
Bolzano	666	*0·9*	1·1	1·8	2·4	**3·5**	2·8	3·4	3·3	*2·5*	3·3	**3·4**	1·2	29·6
Milan	482	2·4	*2·3*	2·8	3·5	**4·0**	3·2	*2·9*	3·2	3·5	**4·8**	4·3	3·0	39·9
Cremona	222	2·6	*2·2*	2·7	2·6	**3·3**	2·8	2·8	*1·8*	2·7	**4·6**	3·7	3·0	34·2
Genoa	177	4·1	4·3	4·2	3·9	3·4	2·8	*1·7*	2·4	4·9	**7·9**	7·1	5·0	51·6
Venice	82	*1·6*	1·6	2·0	2·4	2·9	3·0	2·3	2·5	2·8	**3·6**	2·7	1·9	29·3
Florence	239	*1·9*	2·1	2·7	2·9	**3·0**	2·7	*1·5*	1·9	3·3	**4·0**	3·9	2·8	32·7
Rome	208	3·3	2·6	2·9	2·6	2·2	1·5	*0·7*	1·0	2·5	**5·0**	4·5	3·9	32·6
Naples	489	3·7	2·9	2·8	2·6	2·0	1·4	*0·6*	1·1	2·9	**4·6**	4·5	4·4	33·4
Palermo	234	3·4	2·8	2·7	1·9	1·1	0·6	*0·2*	0·4	1·8	3·2	3·3	**3·7**	25·3
Balkan States														
Trieste	85	2·4	*2·3*	2·8	3·0	3·7	**4·0**	*3·2*	3·7	4·7	**6·0**	4·1	3·1	43·0
Split	420	3·0	*2·4*	3·0	**3·3**	2·7	2·2	*1·2*	1·7	2·9	**4·4**	4·2	3·6	34·5
Corfu	89	6·5	5·5	3·9	3·0	1·9	1·0	*0·2*	0·9	3·1	6·8	7·5	**8·6**	48·7
Athens	351	2·2	1·5	1·3	0·9	0·9	0·6	*0·3*	0·4	0·6	1·7	**2·8**	2·6	15·6
Salonica	129	1·5	*1·3*	1·6	1·9	**2·3**	1·7	*1·1*	1·2	1·7	2·2	**2·8**	2·3	21·5
Istanbul	164	3·2	2·7	2·5	1·6	*1·2*	1·3	1·2	1·7	2·0	2·7	3·6	**4·8**	28·8

PART V

NORTH AMERICA (EXCEPT MEXICO)

CHAPTER XXXI

GENERAL FEATURES

NORTH AMERICA is the third in size of the land-masses of the earth, but its area is less than half that of Asia. It is compact in form; the only inland sea is Hudson Bay, a shallow basin, largely ice-covered much of the year. The Great Lakes, though much smaller, are not completely frozen over in winter, and therefore they have no less influence on the climate than Hudson Bay. The west coast of the continent lacks large indentations, in great contrast to Eurasia. And another important difference is the trend of the main feature-lines; the Western Mountain system of America runs north–south, the mountain ranges of Eurasia west–east, and the greater continuity of the former makes them an effective barrier although they are less lofty than the mountains of Eurasia. Rising steeply from the Pacific Ocean, and consisting of several parallel ranges and intermont basins 500 miles wide in Canada and as much as 1,000 miles in the United States, the system is a formidable rampart in the prevailing westerly winds, and the complicated topography gives rise to very varied climatic conditions. On the east the ranges fall abruptly to the Great Plains, in places 6,000 feet above the sea, and the Great Plains slope gradually to the vast lowland in the middle of the continent which includes Hudson Bay, the west of the Great Lakes, and the Mississippi valley, and affords a wide open passage from the frozen wastes of the north of Canada to the sub-tropical shores of the Gulf of Mexico, for there is no transverse barrier. Most of the gently rolling lowlands are between sea-level and 2,000 feet, highest in the neighbourhood of the international frontier, but it is possible to go from the Barren Grounds to the Gulf without rising above 1,000 feet. The Appalachians with ranges of 4,000 feet, and the heights of northern Quebec and Labrador, are lower and less continuous than the western mountains, and have comparatively little effect on the climate of the

Fig. 121. Place-names mentioned in the text.

surrounding country. The lowlands of Europe, on the other hand, are in the west and north without a mountain-barrier to cut them off from the ocean, which, assisted by the bordering seas on the north and south of the continent, extends its influence far to the east. But the north and south of Eurasia are climatically severed, especially in Asia, by the east–west ranges and elevated plateaux of the heart of the continent.

Oceanic Conditions

The North Pacific Drift is a continuation of the Kuro siwo, the counterpart of the Gulf Stream of the Atlantic; it is less important than the North Atlantic Drift, owing to the less volume of warm water in proportion to the size of the ocean which the Equatorial Currents pour into the North Pacific, to mixing with the cold Oya siwo, and to the fact that the basin is almost enclosed in the north. The air temperature in January between Japan and British Columbia has a positive anomaly of about 20°, the corresponding region of the North Atlantic about 40° (p. 308). The Drift, propelled by the westerlies, meets the American coast in the neighbourhood of the mouth of the Columbia River, and divides; one branch goes northward and gives British Columbia its mild winters, the other southward as the cool California Current which greatly modifies the climate of the coast, bringing low temperatures, scanty rainfall, but much fog; it corresponds to the Canaries Current off north-west Africa.

On the east coast the cold Labrador Current goes south from Baffin Bay to Newfoundland. Its Arctic water and great masses of ice, much of which does not melt till it reaches the warm Gulf Stream on the Banks, are responsible for the very cool summers of the Labrador coast. Cold water creeps south between the Cold Wall and the United States coast, but here its influence is not prominent, since it is narrow and is overshadowed by the Gulf Stream. The Gulf Stream, a massive and very warm current, flows near the coast round Florida to Newfoundland, but the direct benefit which America derives from it is less than might be expected, for in winter, when a warm current can have most effect, the prevailing winds are off-shore; even in the coastal belt the rigorous winters are not much tempered by the warm water. In summer the on-shore

winds blowing over it are hot and moist, and when these qualities are specially pronounced they form 'heat waves', an unpleasant element in the climate of the eastern States.

The Gulf of Mexico, the source of part of the Gulf Stream, is always hot, and the air over it is charged with moisture, which explains in part the heavy rainfall of the south-east of the United States. In winter the warm damp air of the Gulf is conducive to low pressures, and favours the spread of 'cold waves' from the interior of the continent to its sub-tropical shores.

North America extends from the tropic to beyond the Arctic Circle, and the length of the day changes greatly from winter to summer; this is a very real element of the climate both in itself and as affecting temperature:

	Number of Hours with sun above Horizon	
Lat. N.	*21 Dec.*	*21 June*
30°.	10	14
50°.	8	16
66·5°	0	24

CHAPTER XXXII

AIR-MASSES. PRESSURE AND WINDS

Air-Masses

North America is invaded by strongly contrasted air-masses which travel far (with much modification) under the control of the pressure-systems. The most clearly distinguished[1] are:

(*a*) *Arctic and Polar.* The former, maritime and continental, originates on the frozen ocean and the Canadian archipelago; the latter, continental, on the expanses of the north-west interior of Canada. They are specially prominent in winter, when the surface air is intensely cold and dry, with a strong inversion of temperature at a few thousand feet. The cold air spreads south behind depressions crossing the continent, and when its advance is massive and rapid it is known as a cold wave (p. 411) and may give northers (p. 411). Like other polar air-masses it is warmed from below if it travels over a warmer

[1] Willett, H. C., *American Air Mass Properties*, 1934.

surface, an interesting case in North America being the passage of the Great Lakes (p. 407). In summer the polar air, cold in the far north, is soon warmed when it moves south over the heated lands, and it is also moistened by evaporation and transpiration from the vegetation especially in the south-eastern States; in the middle of the continent this source is largely lacking and the air remains fairly dry. Convection is liable to cause thunderstorms in favourable synoptic situations when the air is moist.

Polar Pacific air is in winter relatively warm and moist in its surface layers which are resting on a warm ocean, but the upper layers are cool and therefore the lapse-rate is steep, the result being liability to much heavy cumulus cloud and squally showery weather. When the air invades the continent it may give considerable precipitation on the western mountain-ranges, but on the plains of the interior, which are very cold, the surface air, now dry after the loss of water on the mountains, is chilled and the air-mass becomes stable and yields little or no precipitation, but much low stratiform cloud may result from turbulence; thus the Pacific air here resembles the continental polar air described above. In summer the weather on the ocean is much less disturbed (p. 399); in the continent the heat of the land increases the instability of the air, but the dryness after crossing the mountains precludes much precipitation unless the heated air reaches the eastern States and derives vapour from the vegetation, which may be sufficient to provide considerable rain; in summer as in winter polar Pacific air in the interior becomes similar in some respects to continental polar. Polar Pacific air approaching the shores of California has to travel over an abnormally cool sea-surface which cools its lower layers, and fog and low stratus cloud are frequent in the stable moist air.

Polar Atlantic air invades the continent mostly in summer. It differs from polar Pacific largely as a result of its passage over the cold Labrador Current; in winter this influence is not large, but in summer it is one cause of fog on the seas round, and especially south-east of, Newfoundland when air-movement is sluggish, and of low cloud and drizzle when it is stronger. Polar Atlantic air often travels south over the sea and returns towards west and north off the south-eastern

States, crossing the warm waters of the Gulf Stream from which it acquires such heat and moisture that it becomes almost tropical in character (differing little from tropical Atlantic air), and may give heavy and continuous precipitation on the hot land.

(*b*) *Tropical.* Tropical Atlantic air and Tropical Gulf air are very similar, both being conditioned on abnormally hot seas, the former on the Gulf Stream and adjacent waters, the latter on the Caribbean and the Gulf of Mexico. They are hot, moist, and unstable, up to great heights, and their instability is increased in summer when they invade the hot lands of the southern and eastern States to which they give heavy precipitation; even the middle of the continent often gets rain from them. Tornadoes (p. 401) are associated with cold fronts advancing from the west into this tropical air. In winter the cold land stabilizes the surface layers of tropical air, but the higher layers continue hot and moist, and frontal interaction with polar air gives much precipitation over large areas.

Pressure and Winds

Winter. In January (Fig. 122) the sub-tropical high pressures are intensified over the cold continent; and far to the north-west a large 'cold' anticyclone, an extension from that of the Arctic, builds up. The planetary low pressures of the zone are divided into the Aleutian and Icelandic systems, the gradient (as shown by the 'sea-level' isobars) being remarkably steep over south-east Alaska. Cyclonic activity is notably vigorous; depressions are probably more numerous than in any other continent, and they travel about twice as fast as those of Europe. Most originate in the Polar, Arctic, and Inter-arctic fronts (Fig. 4); the col between the warm sub-tropical anticyclone in the south-west and the cold anticyclone of the north-west also strongly favours cyclogenesis. Most depressions alternate with anticyclones, making the weather more than usually variable. Sometimes a single system dominates the weather from Hudson Bay to the Gulf of Mexico, and owing to the lack of a transverse mountain-barrier the winter cold of north Canada or the summer heat of the Gulf spreads over much of the continent, modified with distance but very per-

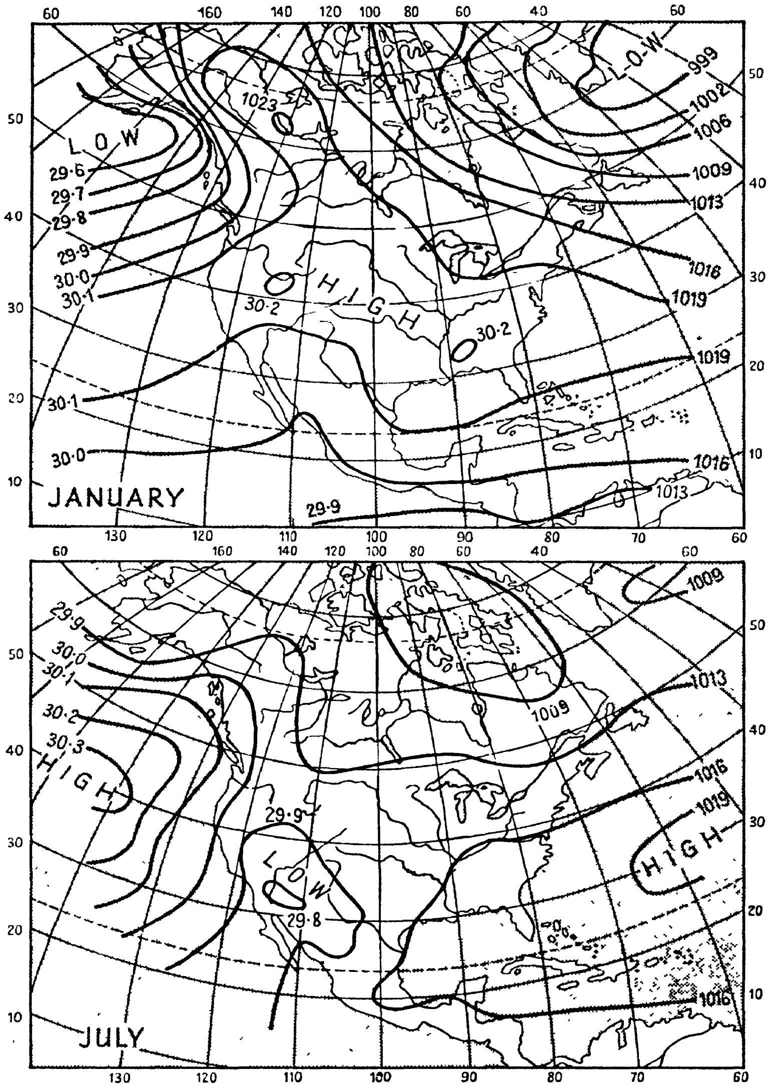


FIG. 122. Mean isobars and winds (over Canada, based on T. J. G. Henry, rest of continent on C. F. Brooks and G. L. Page).

ceptible. The St. Lawrence region has perhaps the most variable weather owing to the convergence there of the much frequented cyclone tracks of the continent; the dry air brought from the interior by NW. winds, bitterly cold in winter, warm in summer, is in strong contrast to the humid and often drizzly weather, raw and cold in winter, damp and cool in summer, of the NE. and E. winds from the cold seas off Newfoundland; southerly winds are warm in winter, hot and enervating in summer.

In the east of the continent W. and NW. winds, blowing between the high pressures of the interior and the low of the North Atlantic, predominate and bring cold dry air and clear skies from the interior; but other directions are frequent under the control of pressure-irregularities. In many places the topography deflects the winds, as happens in much of the Gulf of St. Lawrence and in the Strait of Belle Isle where SW. and W. and NE. winds are most frequent. The Prairie Provinces of Canada south of lat. 55° N., being south of the axis of the col, are largely dominated by the gradient from the sub-tropical high pressures of the U.S.A., and their prevailing winds are westerly (sometimes chinooks, p. 405). N. winds predominate on the shores of the Gulf of Mexico, but Texas, particularly in the west, has variables, and at Galveston and some other stations the prevailing winds in January are SE. The cold N. winds are so prominent at times that they have acquired a local name, Northers; they may continue far over the Gulf and even cross Central America into the Pacific (p. 413). The region between the Appalachians, the Mississippi, and the Great Lakes is exceptional in having SW. winds in winter and in summer, associated with high pressures over the south-east of the United States.

The wind-directions on the Pacific coast suggest that the mountains, or the continental high pressures, or both, present an obstacle to the westerlies. But the polar Pacific air (and occasionally other types), which reaches the coast north of lat. 40° N., is unstable and in part is able to surmount the ranges, giving long and heavy rains on the windward slopes near the sea. Here the prevailing winds are S. and SW. (E., SE., and S. on the coast of British Columbia and Alaska), along- and somewhat off-shore; they correspond to the westerlies of the

British Isles, and like them are rainy, mild, and strong, and variable in direction and force, with frequent gales. The heavy rainfall is restricted to the littoral since the mountains prevent the great landward extension which is such a valuable asset in Europe. The sheltered valleys of the Fraser and Columbia

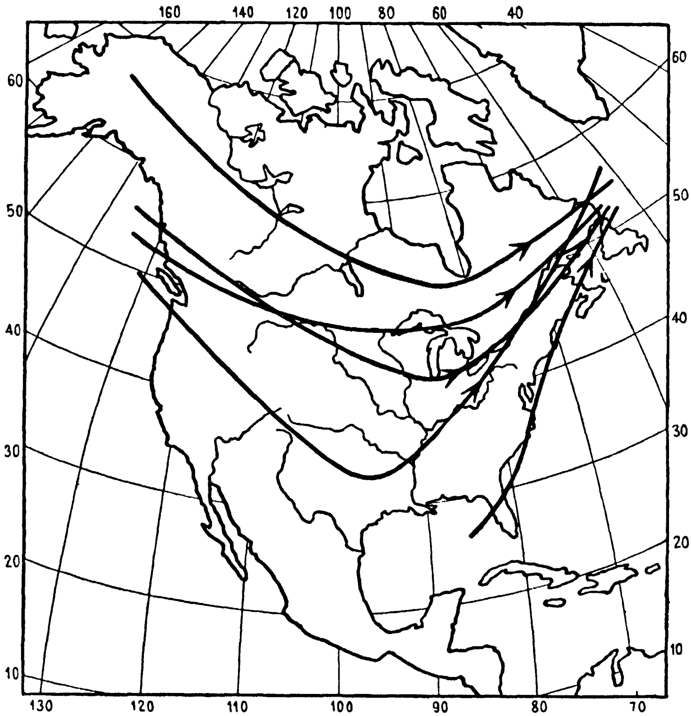


FIG. 123. Generalized tracks of depressions.

and their tributaries enjoy usually dry weather with light winds. At sea off Vancouver Island gale force (over 32 miles an hour) is frequent in winter:

Nov. . .	10 days	Jan. . .	12 days	Mar. . .	9 days
Dec. . .	15 „	Feb. . .	12 „		

But Victoria has only 41 days a year with gales, Vancouver (city) none. The coast of Oregon has more variable winds, the most frequent being between E. and S.; off California the fairly constant NW. winds often reach gale force; Lower California, however, is more under the influence of the North Pacific

anticyclone and has N. winds, really the trade-wind, as are also the easterlies of the Gulf of Mexico.

The winds on the plateau of the south-west are too much affected by the topography to admit general description.

Some belts enclosing the most frequented tracks of depressions in winter are indicated by the arrows in Fig. 123. An outstanding feature is that the majority of the tracks cross the continent in a generally W.–E. direction; most of them start well north of the international border, curve south to the middle of the continent, and continue ENE. over the Great Lakes and down the St. Lawrence to the Atlantic. Another more scattered group goes SE. from the west of the United States to the southern States and thence NE. to join the previous group. Over and off the east coast, apparently favoured by the Gulf Stream, is an oceanic group, originating in the Gulf of Mexico and east of Florida (many of them as hurricane tracks), which converges with the continental groups in the neighbourhood of the Maritime Provinces. A distinct but small group originates in the Arctic and advances south and east in the far north of Canada. The weather of large areas depends on the size and intensity of the dominant pressure-system, high or low, and the track it follows.

Summer. With the advance of spring the high pressures on the continent break up and in April they almost disappear; the isobars for May foreshadow the summer conditions which culminate in July (Fig. 122). The sub-tropical high pressures are interrupted (on the surface) by the warm land, on which a shallow trough of low pressure connects the equatorial and temperate zones; but above about 5,000 feet the high pressures persist over the arid plateau of the south-western States with more intensity than in winter, and form a ceiling which stops the ascent of the hot surface air before it can cool to its dew-point and form cloud. The North Atlantic anticyclone is prominent over the south-eastern States, and more prominent is the North Pacific anticyclone which spreads north, replacing the Aleutian low pressures of winter, to dominate the whole west coast; the frontal zones on the oceans are eliminated.

The winds in the east and south of the continent show a monsoonal change, but not a complete reversal. On the east

coast (except Labrador where W., N., and E. are all frequent) they blow from the south-west, on the coast of the Gulf of Mexico from south and south-east. The plains west of the Mississippi have humid southerlies. On the Pacific coasts the wind shows a marked tendency to blow into the continent, from the west and north-west in British Columbia, and from north and north-west in Washington and Oregon almost with the constancy of the trades; but the bold coastal topography has a strong influence, the winds nearly always following the channels whatever the general directions may be. California has northerlies, very strong in spring and summer north of San Francisco (mean speed at Point Reyes 25 miles an hour in June); San Francisco has almost constant westerlies setting in through the Golden Gate, and off Santa Barbara also westerlies are almost constant. In the interior and east of the continent cyclonic activity continues as in winter though less vigorous, and gives more variable winds.

In spite of the mean pressure being lower than in winter the summer weather is finer, the winds lighter, and the relative humidity lower; Canada has the advantage of much longer daylight—the whole 24 hours in the north. But summer is the rainiest season in the interior, for the warm air contains more vapour, and its instability on the hot land favours rain, both general and sporadic, in thermal depressions.

The bold relief of the west of the continent gives rise to many prominent local winds. The chinook of Alberta is described on page 405; the same region in summer has well-marked katabatic winds from NW. in the cold hours (mean frequency at Calgary 86 per cent. at 0600), and anabatic from SE. (60 per cent. at 1500) in the hot.

The mean frequencies of wind-directions at stations scattered over the continent are given below, but owing to the strong local influences of relief and of juxtaposition of land and sea or lake, and the failure of some stations to separate the observations taken at different hours, they give only an approximate picture of the general air-movements:

WIND DIRECTIONS, MEAN PERCENTAGE FREQUENCIES

Canada		*N.*	*NE.*	*E.*	*SE.*	*S.*	*SW.*	*W.*	*NW.*	*Calm*
Cape Race, Nfld.,	Jan. .	7	9	3	5	7	14	29	21	5
	July .	2	8	5	2	7	37	30	4	5

WIND DIRECTIONS (*continued.*)

		N.	*NE.*	*E.*	*SE.*	*S.*	*SW.*	*W.*	*NW.*	*Calm*
Chesterfield, NW. T.,	Jan. .	38	4	3	4	4	2	5	38	2
	July .	22	7	8	8	19	8	8	19	1
Dawson City, Y.T.,	Jan. .	17	0	1	4	35	1	0	1	41
	July .	27	1	2	3	19	3	1	4	40
Edmonton, Alta.,	Jan. .	8	12	5	7	9	19	13	21	6
	July .	5	12	7	10	10	15	14	23	4
Father Point, Que.,	Jan. .	8	8	6	3	7	23	15	20	10
	July .	1	12	5	1	2	28	29	4	18
Prince Rupert, B.C.,	Jan. .	5	4	16	20	6	2	3	2	42
	July .	1	1	3	8	8	11	16	2	50
Quebec, Que.,	Jan. .	3	22	5	1	3	32	19	10	5
	July .	4	19	6	3	9	36	10	12	1
Swift Current, Sask.,	Jan. .	5	4	3	5	7	31	22	21	4
	July .	5	8	4	12	10	24	13	20	4
Vancouver, B.C.,	Jan., 0730	5	16	39	24	2	3	4	3	4
	1430	1	14	22	22	5	8	15	12	1
	July, 0730	3	16	26	32	3	2	7	9	2
	1430	0	4	9	17	6	17	30	17	0
Winnipeg, Man.,	Jan. .	10	3	3	17	12	11	14	27	3
	July .	12	9	5	17	13	11	11	18	4
Tatoosh Is. (off C.	Jan. .	0	6	49	7	18	8	9	3	0
Flattery)	July .	2	4	4	1	38	32	16	2	1
Triangle Is. (50·5° N.,	Jan. .	6	14	4	23	0	18	7	17	11
129·5° W.)	July .	3	4	2	12	2	16	14	29	18
U.S.A.										
Boston, Mass.,	Jan. .	11	5	3	5	5	24	24	23	0
	July .	7	7	8	6	8	32	21	11	0
Charleston, S.C.,	Jan. .	17	16	6	5	7	19	16	14	0
	July .	5	7	7	9	24	31	13	4	0
Chicago, Ill.,	Jan. .	7	7	4	8	14	18	21	20	0
	July .	7	24	9	12	10	20	12	6	0
Cincinnati, Ohio,	Jan. .	6	10	9	16	10	19	11	18	1
	July .	7	9	9	16	12	21	9	12	6
Eureka, Calif.,	Jan. .	12	9	10	30	15	12	4	5	3
	July .	30	2	1	2	7	17	11	28	2
Galveston, Texas,	Jan. .	24	11	12	20	12	6	4	11	0
	July .	4	3	4	23	42	15	6	3	0
Key West, Fla.,	Jan. .	13	48	15	6	3	3	2	10	0
	July .	3	14	39	23	8	7	3	6	0
Memphis, Tenn.,	Jan. .	12	12	7	11	15	15	9	18	0
	July .	10	10	8	10	16	21	9	15	2
New Orleans, La.,	Jan. .	14	20	13	13	12	11	6	11	0
	July .	6	6	5	12	13	24	21	21	1
Portland, Ore.,	Jan. .	7	4	21	20	13	15	4	16	0
	July .	25	3	2	6	5	4	4	51	0
Reno, Nev.,	Jan. .	10	8	13	12	6	4	40	7	0
	July .	4	3	8	17	6	6	50	6	0
San Diego, Calif.,	Jan. .	10	14	16	10	8	8	10	23	1
	July .	6	1	1	1	12	22	31	26	0
San Francisco, Calif.,	Jan. .	23	13	4	17	7	6	10	20	0
	July .	0	0	1	1	2	58	36	2	0

For comparison of the monsoonal influences in Asia and North America we have the mean percentage frequencies of wind-directions in east Asia (mean of stations in Gulf of Chihli) and eastern North America (mean of five coastal stations):

	N.	*NE.*	*E.*	*SE.*	*S.*	*SW.*	*W.*	*NW.*	*Calm*
East Asia									
Jan. . . .	25	6	5	4	8	13	11	23	5
July . . .	6	7	11	19	26	12	4	7	7
Eastern N. America									
Jan. . . .	13	8	4	3	7	14	24	20	6
July . . .	11	8	8	7	13	22	16	9	7

The more variable winds and less complete change from summer to winter in North America are no doubt due partly to its smaller area but chiefly to the lack of a transverse barrier to separate the cold dry polar air of the north from the tropical air of the Atlantic and the Gulf of Mexico; the barring of the westerlies by the western mountain-system athwart their course may conduce to the same result, vigorous cyclonic activity.

Tornadoes. The whole of the United States east of the Rockies experiences tornadoes. These rapidly revolving whirls, most of them with a diameter of about 400 yards, travel in a more or less straight line along their path of destruction at a speed of 20 to 40 miles an hour, and usually die out after about 20 miles. The winds near the core may attain speeds far above 100 miles an hour, among the highest wind-velocities on the earth. Tornadoes are secondary disturbances near the cold fronts of extensive low-pressure systems, and many may develop on the same day in a suitable meteorological environment and claim hundreds of lives. They are most frequent in the Plains where the open passage facilitates the meeting of cool dry polar air-masses from the north and hot moist tropical air from the Gulf, and they are specially violent in the valleys of the middle Mississippi and the lower Missouri where, in the heart of the continent, the opposing winds have the greatest contrasts of heat and humidity (Fig. 124). They occur in the warmer months, most in spring and early summer, and almost all in the warmest hours of the day. The following description is given in the *Climatology of the United States* by an

eyewitness of a tornado which passed over Sherman, Texas, in May 1896:

When the cloud passed in front of me it seemed to be going at the speed of a galloping horse. The speed was not so great but that almost any one running to the east or to the west could have got

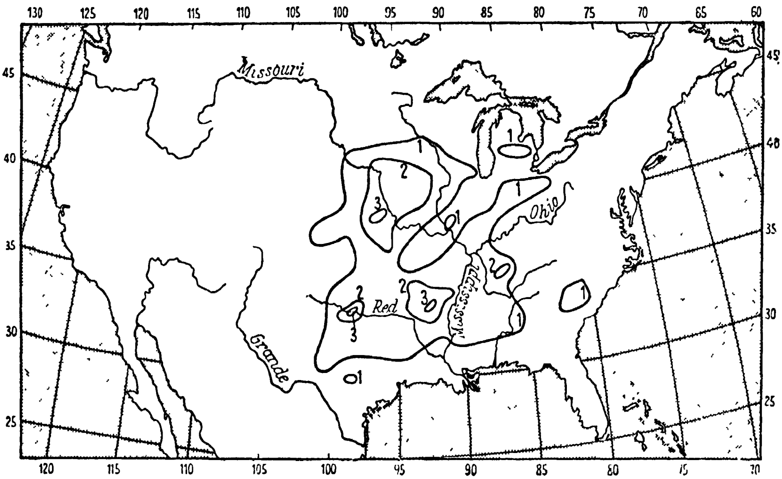


Fig. 124. Mean annual number of tornadoes (in squares with 100-mile sides), based on K. B. Allan.

out of the way. The cloud swelled out above the ground, but the top of it was higher than the sides. It seemed to be churning up all that it touched and throwing out the fragments at the top. At the same time as it moved along the mass had a rotary motion. It whirled round and round in a direction from right over to left. Only the outlines of the mass could be distinguished. It was impossible to see into it. Houses and other things went up as the cloud reached them, disappearing in the revolving interior. At the top and around the edges I could see things whirling and then falling as they got beyond the edges. The revolving velocity was so great that it set the adjacent air in motion, and the lighter things, such as leaves and twigs and bits of pine and particles of mud, circled far outside of the cloud and fell at considerable distances from the path of the cyclone.

The hurricanes which work havoc on the coasts of the Gulf are described in the chapter on the West Indies (p. 519).

CHAPTER XXXIII

TEMPERATURE

In the higher latitudes the farmer's main consideration is the duration of summer warmth adequate for crops or grazing, the

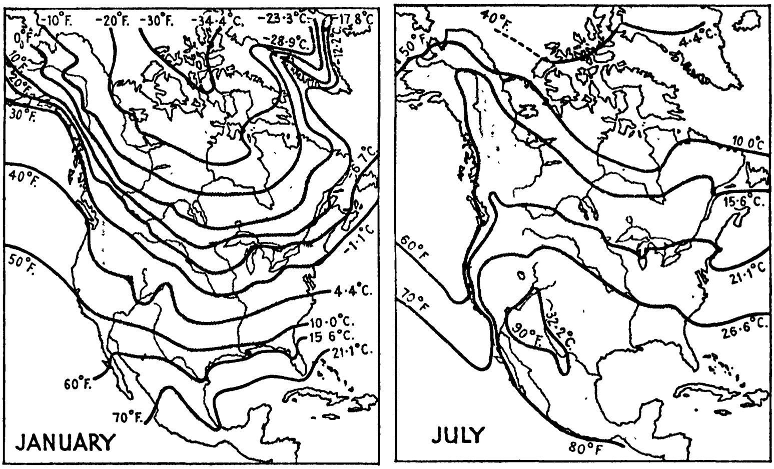


FIG. 125. Mean isotherms (based on C. F. Brooks, A. J. Connor, and others.)

winter cold being of less significance. The 60° isotherm for the warmest month forms a convenient approximate limit of any possible agriculture; beyond are only the northern forests and tundra. On the other hand, in middle latitudes the hazard of killing frosts is the controlling factor, the summer heat being more than sufficient. Hence in the north and east of North America the warm season, but in the south of Canada and the north of the United States the cold, claims most attention. All the continent except the littorals of the Pacific and the Gulf of Mexico has a large range of temperature.

WINTER

In January (Fig. 125) almost the whole of Canada and the north interior and east of the United States have mean temperatures below 30°. The 50° isotherm skirts the shores of the Gulf of Mexico, and the 70° line appears over the south of Florida. The north of Canada is the coldest tract, with a mean

below −20°. The only parts of Canada which have never recorded temperatures below −30° are Newfoundland, Nova Scotia, and the west of British Columbia; zero has been recorded even in Vancouver Island. The intense cold results partly from the spreading south of polar air-masses over the vast open plains, partly from vigorous local cooling of the land surface.

The isotherms swing farthest south in the Mississippi valley, and trend northward as they approach the east coast; thus the 30° line passes through St. Louis, and reaches the east coast in Long Island. In the west they diverge from the parallels of latitude to run north-west to south-east, almost parallel with the coastline; here the warm waters of the ocean are as effective a source of heat as direct insolation. The 40° line runs the length of Vancouver Island, much as in the British Isles. The cold increases rapidly inland, and the 30° isotherm is reached within 40 miles, the warm oceanic conditions being shut off by the mountain-ranges; in Europe the 30° isotherm is 500 miles inland.

British Columbia resembles north-west Europe in the mild and moist climate of its coasts, which have the double advantage of warm cyclonic weather from the ocean, and shelter by the mountains from cold continental air-masses; but immediately behind the Coast Range, in the Fraser valley, we seem to be in central Europe. Victoria has a January mean of 39°, Vancouver 36° (abs. min. 2°, recorded once when very cold polar continental air had made its way west from the interior, an unusual occurrence), Kamloops, 250 miles from the open Pacific and half-way from the coast to the Rockies, 22° (abs. min. −37°), Prince George 13° (abs. min. −58°). The sheltered valleys are free from strong winds, and the winter cold is pleasant and exhilarating when skies are bright, but temperature is low since the long north–south valleys give passage to air from the far north. The bold relief of the land conduces to prominent weather types, including föhn winds, which, like the chinook east of the Rockies, are valuable in rapidly melting snow. The interior uplands of British Columbia (2,000–5,000 feet) have severe cold in winter, the January mean being about 14° with minima down to −55°, and frost occasionally occurs even in July. The Selkirks and the Rockies rise to over 10,000 feet for long distances and have perennial snow.

East of the Rockies we enter an extreme continental climate. At Calgary the January mean is 13°; the altitude of the High Plains in this neighbourhood is over 3,000 feet with a steady descent eastward, but in spite of this the temperature falls lower towards the east, since distance from the Pacific Ocean more than neutralizes decrease in altitude; the January mean is 12° at Medicine Hat (2,144 feet), 0° at Qu'appelle (2,115 feet), —2° at Minnedosa (1,400 feet), —3° at Winnipeg (760 feet). There is a similar fall in temperature in the United States:

	Alt. feet	*Mean temp. Jan.*		*Alt. feet*	*Mean temp. Jan.*
Cheyenne, Wyo.	6,088	26	Des Moines, Iowa	861	21
North Platte, Neb.	2,821	23	Davenport, Iowa	580	22
Omaha, Neb.	1,103	21	Chicago, Ill.	824	24

The region farther east is less cold, but continentality still asserts itself strongly.

The warmth near the east of the Rockies is the result not only of proximity to the ocean but also of dry warm west winds ('Chinooks') on the south of depressions passing in high latitudes. The air obtains heat and moisture over the Pacific, and in favourable circumstances acquires föhn characteristics in its passage over the mountain-ranges. Chinooks are most pronounced along the east foot of the Rockies, where they melt the snow and make grazing possible throughout most winters, but their beneficial effects may be felt 300 miles from the mountains. They are a valuable asset from the south of Colorado as far as settlement has advanced north in Canada, and even in the lower Mackenzie basin. The rise in temperature when the chinook sets in can be remarkably rapid; as much as 40° in 15 minutes is occasionally recorded. As a rule the temperature does not exceed 45°, but that feels very warm after the intense cold of a spell of anticyclonic weather; the chinook may continue for several days. Alberta is specially favoured, and Calgary has recorded 76° in February; the plains near the Rockies south of 52° N. are usually bare of snow. When chinooks are strong and frequent the western prairies have a comparatively open season, when absent a severe winter with heavy losses of stock.

The day preceding had been mild with a soft wind blowing out

of the east, sure harbinger of bad weather. The morrow, however, brought a lower temperature and stronger wind. That night the wind dropped. We awoke to find the thermometer standing at $-52°$. The steam rose in little clouds from the stables, and the smoke from the house chimneys went up so straight and far, ere spreading out into a huge mushroom-shaped growth, that it could easily have been mistaken for a natural cloud. Little pools of mist marked the spots where the cattle stood in huddled bunches, the heat from their bodies combined with their breath hanging over them exactly as mist will gather over a pool on a chilly summer's night. . . . Our main bunch of horses were on a pasture four miles from home when the blizzard struck. In an ordinary winter they would have been able to forage for themselves and grow fat. It was ten days before a man could be spared to see how they were doing. . . . When the snow finally cleared dead horses were to be found with manes and tails eaten off by their starving companions, lying in every sheltered corner. . . . And then almost as suddenly as it had commenced, the siege was raised; the snow vanished like magic, grass coming up green and fresh as fast as it had disappeared. Horses that had seemed about to die fattened over night (SYKES, quoted by KOEPPE in *The Canadian Climate*).

Manitoba has the coldest winters for its latitude, especially the north-east near Hudson Bay where Churchill has never recorded a temperature above 32° in January and has known $-57°$; here are no warm chinook winds. Near the Great Lakes temperature increases rapidly, and on the north shores of Lake Superior the January mean is 10°. The warmest part of Canada in winter, excluding the west coast, is the Lake Peninsula of Ontario, which lies farthest south and is most favoured by the influence of the lakes. At Toronto the February mean is 22°, absolute minimum $-28°$; much of the peninsula has only 3 months with a mean below 32°, a clear advantage over the St. Lawrence valley with 5 months. Eastward from the lakes the temperature first falls and then rises again near the east coast; the mean for the coldest month at Ottawa is 12°, at Halifax 23°. These stations are hardly comparable with Winnipeg which is farther north, but even the bleak coast of Labrador is warmer (but damper) than the interior; inhospitable summers rather than specially cold winters are its most unpleasant feature; its coasts are heavily ice-bound against navigation except in the months June to November.

It is interesting to trace the influence of the Great Lakes in more detail. They cause a slight northward swing in the isotherms in October by their retention of the summer heat, and the bend becomes more pronounced till January, after which it diminishes, and in March they cease to provide warmth. Their east shores are warmed more than the west under the westerly winds. Milwaukee, on the west of Lake Michigan, has a January mean of 21°, Grand Haven on the opposite shore 25°. A strip of country 20 to 30 miles wide along the east of Lake Michigan is known as the Fruit Belt, because it is so much warmed that peaches, grapes, and other tender fruits are cultivated with a success impossible in neighbouring districts not similarly favoured. But even in Michigan a night of frost unduly late in spring or early in autumn may do damage to agriculture amounting to millions of dollars. Lake Erie also warms its shores; the lowest record at Toledo, on its south shore, is −16°, but Columbus, 100 miles south of the lake, has recorded −20°.

The Grape Belt which extends along the southern shore of Lake Erie for a distance of about 60 miles, and is from 2 to 6 miles wide, has the most temperate climate in New York State except the region along the Atlantic coast. This is directly due to the tempering influence of the lake, which holds vegetation in check in the spring until danger from frost is over, gives long mild autumns with unusually late fall frosts, and winters much less severe than elsewhere. The tempering influence of the lake is noticeable for a distance of about 30 miles inland (*Climatological Data for the United States*).

The effect of Lake Ontario is specially valuable when very cold waves sweep down from Canada, the difference in temperature between the north and south shores amounting even to 20° (ibid.).

The shores of the lakes except the south of Michigan are often frozen and the harbours closed in winter (in general during December to March), and the melting of the ice delays the coming of spring.

The Atlantic Provinces of Canada with their peninsular configuration have strong maritime tendencies in spite of their situation on the lee side of the continent. The mean winter temperature is 10° to 20° higher than in the Prairie Provinces,

and the lowest readings also are much higher. Spring is late and cold, being delayed till the snow and ice melt, after which temperature often rises fast; in the valley of the St. Lawrence 80° may occur in May. Changes are liable to be large and sudden, tropical air-masses in front of depressions bringing abnormal warmth, to be followed by very cold polar air behind the cold front. Cold bleak weather is usual in Newfoundland, and even St. John's on the coast has recorded −21°, but the temperature may rise to 60° in midwinter.

The coldest winters of North America are in the region between Hudson Bay and Alaska. The north coasts are less cold, since even the ice-covered seas and channels provide more warmth than the land during the polar night, but the strong winds, frequent blizzards, and high humidity make the cold more difficult to bear. In the interior the cold is intense, especially in the valley-bottoms, with monthly means far below freezing-point in October to April. Lakes and large rivers freeze to a depth of more than 5 feet, and even 8 feet has been reported. In the lower Mackenzie valley the temperature falls at times below −70°, and the monthly means are below freezing-point for 7 months out of the 12. But the air is dry and calm, and the weather often beautifully fine and invigorating. Fort Good Hope, on the Mackenzie near the Arctic Circle, has had temperatures below zero in all except the 3 summer months, and one of the lowest official records in Canada, −79°. But Fort Vermilion, in the Peace River valley, has recorded −78°, and this station has had 98° in summer, giving an extreme range of 176°. Dawson City has recorded −68°; the Yukon River freezes in September and remains frozen till late May; Snag airport, in the south-west of the Yukon, recorded −81° in February 1947. The Barren Grounds have January means below −20° (the islands in the farthest north below −30°), and the coldest tract, with a mean below −25°, is probably between Boothia Peninsula and the north-west of Hudson Bay. In much, probably all, of this region the ground is permanently frozen to a depth of, in places, 200 feet, except for the summer thaw of the surface 3 or 4 feet; the south boundary of this frozen ground, 'permafrost', runs south-east from the Yukon and Great Slave Lake to James Bay and thence east to

Labrador. The west coast of Alaska has much higher temperatures than the interior, but still far below freezing-point, and the damp and often foggy air makes the climate less pleasant.

The winters are very variable from year to year; the official reports quote Fort Good Hope where the February means were —33° in 1925, 1° in 1920. Such variability is not unusual in very cold regions, since the intense cold is largely a result of local 'inversion' conditions, and may disappear if they break down.

Hudson Bay is largely frozen and has much less influence on its neighbourhood than its size might suggest. The shores have a selvedge of ice many miles wide except in the months July to October, and drift ice may be met in the Bay all the year. The whole of the middle is completely frozen over in winter, and the mean temperatures are similar on the west and east shores; but latitude shows its strong effect in the difference between the south and north, the January mean being —6° at Moosonee, James Bay, —24° at Coral Harbour, Southampton Island. The weather is much more stormy, cloudy, and bleak than in the forests and prairies and the high plains of the west, and there is no chinook to give even occasional warm spells.

The warmest winters of the continent are in the lower Colorado valley. At Yuma, 141 feet above the sea, the January mean is 54°, and 81° has been recorded, but, as is usual in an arid climate, the nights are cold, absolute minimum 22°. On the higher plateaux in this region the nights are far colder; 10° has been recorded at Fort Grant, Arizona, altitude 4,916 feet, —13° at Santa Fé, New Mexico, 7,014 feet, where the clear dry air favours very rapid loss of heat. The plateau farther north has much colder winters than Arizona; Salmon, Idaho, altitude 4,039 feet, has a January mean only 18°, absolute minimum —37°; Fort Laramie in the valley of the North Platte River in Wyoming, altitude 4,270 feet, has recorded —48°, and the absolute minimum for the whole of the United States, —66°, was reported from a station in Yellowstone Park. But the cold can be almost as intense in the valley-bottoms at much lower altitudes east of the Rockies, —65° having been registered at Miles City, altitude 2,371 feet,

in the valley-bottom of the Yellowstone River, in the south-east of Montana, $-63°$ at Poplar River similarly situated in

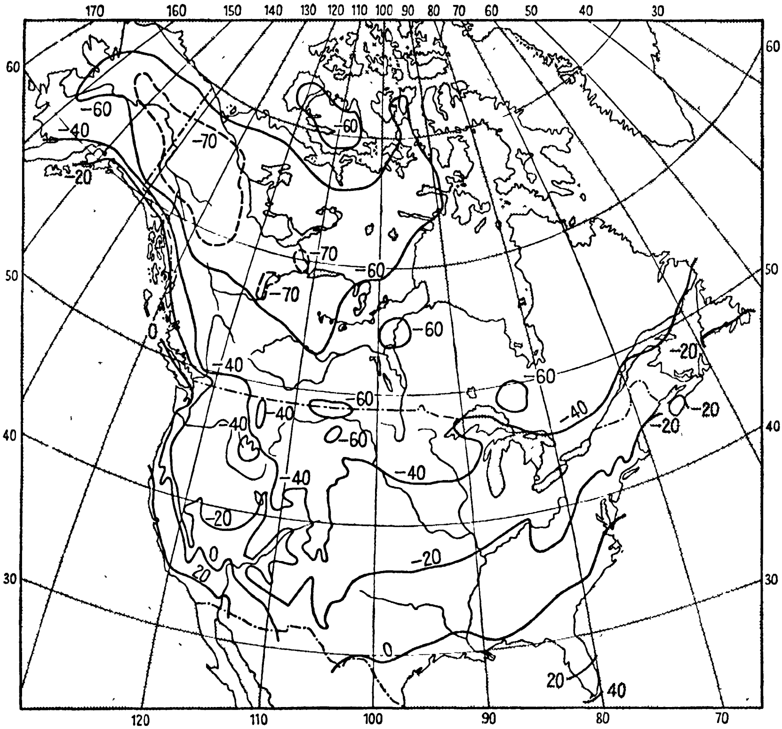


FIG. 126. Absolute minimum temperature (actual, not reduced to sea-level). The isotherms are generalized over the usually small and scattered areas with very low records. (Canada based on most recent data, U.S.A. on *Atlas of American Agriculture.*)

the same State. These areas are too small to be shown in Fig. 126.

The plateaux and mountain-tops have lower means as might be expected from their altitude, but the extremes are not so low; Lake Moraine, Colorado, 10,265 feet, has no record below $-34°$, and even Pikes Peak, 14,111 feet, none below $-39°$. The intense cold in the valley-bottoms is a result of the drainage of the coldest air to the lowest levels, making a strong inversion.

Wallace Craig gives a graphic account of the conditions in North Dakota:

The soil freezes to a depth of 6 feet. The total snowfall is not excessive, but the winter is made odious by the blizzard . . . the fine snow drifts excessively, blockades the roads, and blows into the houses through every crack and keyhole. Drifting snow settles in the valleys; the small tributary valleys may become filled to the brim, and houses in them completely buried. The plains, in contrast, are swept bare in spots. . . .

The sky of Dakota is seldom overcast with clouds. Day after day the fields are blest, from sunrise to sunset, with the undimmed, unstinted light; and the brightness of the days affects men's minds with a brightness and cheerfulness which goes far to compensate for the dullness of the landscape. . . . On nights of full moon the moonlight is so powerful as to hide all but a few of the very brightest stars. On starlit nights in the dark of the moon, the number, the brilliance, the twinkling, and the colours of the stars are heightened to a degree unknown in moister regions.

The cold winter necessitates abundant adaptations in the flora. . . . After travelling for hours over an unbroken treeless plain one suddenly discerns ahead of the train a break in the ground, filled with foliage; soon the train crosses the spot and one sees that it is a sharp-cut river valley (the Cheyenne), filled to the brim with trees, the boughs all ending at the level of the prairie as evenly as if they had been artificially trimmed. The trees in this situation are supplied with water from the soil of the valley, and sheltered from the dry, searing, winds of the plain. . . . Essentially the same condition obtains in winter when such valleys become filled to the brim with snow and the trees are thus protected from the winds which desiccate by freezing.

The Pacific littoral is notably warmer than the Atlantic, but even San Diego has recorded 25°. Key West off the south of Florida is the only station in North America (outside Mexico) exempt from frost.

No account of the American winter can omit a reference to the 'cold waves', which are defined officially as spells having a fall of temperature within 24 hours of at least a certain magnitude, down to, or below a specified figure, the limits being appropriate to region and season. In Florida the fall must be at least 16° and give a reading below 32° in winter, 36° in November and March; in New York the corresponding figures are 20°, 20°, and 28°. The strong cyclonic activity in the continent has already been mentioned. As they travel east some

pressure-systems become elongated in a north–south direction and polar air-masses sweep over great distances behind their cold fronts (Fig. 127); many originate in the north-west where the clear skies of an anticyclone favour intense cold, and as they advance south they bring Canadian temperatures, modified somewhat by the journey, even to the Gulf of Mexico. On the average 3 or 4 cold waves a year reach the eastern States; they are an important factor everywhere in the variable weather

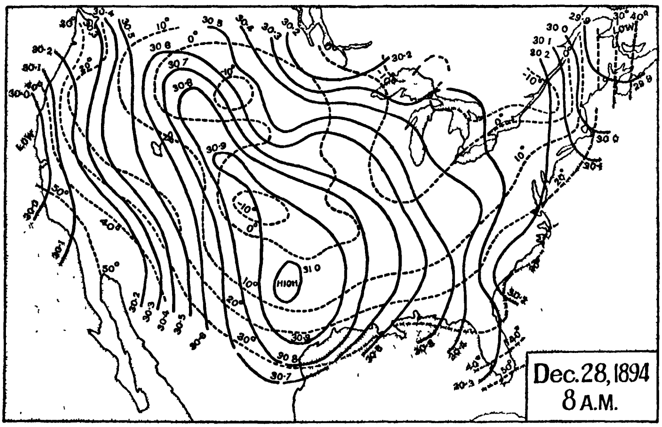


FIG. 127. Isobars and isotherms during a cold wave.

for which the States are noted; the rapidity of the changes results from the rapid movement of the depressions. The inflow of tropical air in front is almost as pronounced as the cold wave which suddenly replaces it behind the cold front. Cold waves are coldest in the north; in the mid-course of the Mississippi the extremes are less, but the changes are more noticeable since the temperature often drops rapidly from well above to well below freezing-point, and this entails the maximum of inconvenience and discomfort. St. Louis has had 74° and −22° in January, that is to say 42° above, and 54° below, freezing-point. In December 1831 the Mississippi was frozen for 130 miles below the mouth of the Ohio; the ice at New Orleans (not on the main river) was thick enough for skating.

Nearer the Gulf cold waves are called Northers. Since the mean temperature is fairly high, the cold is very perceptible. Sometimes sleet or snow falls, but generally the weather is clear, and the norther blows strong and dry for a day or longer,

with a temperature considerably below freezing-point. At San Antonio the January mean is 53°, and 83° has been recorded; but during a norther the thermometer has dropped to 4°. The absolute minimum at Galveston is 8°, at New Orleans 7°. At Houston the arrival of a norther sent the temperature down from 75° at midnight to 22° at 0900. Cold waves reach Florida, and may bring frost almost to the extreme south; Key West, an island station, alone has never recorded frost, its lowest reading being 41°. They appear in a severe form in all the Atlantic States.

The cold wave in the plains is shallow—it may be less than 3,000 feet deep when it reaches the southern States—so that it is effectively dammed on the west by the mountains and prevented from being dissipated. This continuous north–south barrier is thus a main cause of the remarkable penetration into low latitudes, no exit to the west being available before the isthmus of Tehuantepec (p. 514). The cold waves of the high plateau of Arizona and New Mexico, which are keenly felt, and preclude the cultivation of sub-tropical fruits that flourish in California, originate on the plateau itself farther north; they sometimes spread down to the Pacific coast, and though less prominent are well known even beyond the Mexican frontier.

The blizzards of Canada and the northern States are cold waves of a special type behind a cold front, with a gale of wind and the air full of dry powdery snow. The wayfarer easily loses his bearings and cannot survive for long without shelter.

Freezing of Rivers. The rivers of Canada (except west of the Rockies) and of the north interior of the U.S.A. are frozen in winter; the average dates give some idea of the duration:

the Mackenzie at Fort Simpson, from 30 Sept. till 15 May,
,, at Aklavik, from 15 Sept. till 10 July;
the Mississippi at St. Paul, from 7 Dec. till 21 Mar.,
,, south of St. Louis, rarely frozen;
the Missouri at Bismarck, from 25 Nov. till 31 Mar.,
,, at Kansas City, from 12 Dec. till 2 Mar.;
the Hudson at Albany, from 17 Dec. till 23 Mar.;
the Ohio, rarely frozen.

The St. Lawrence is closed to navigation at Montreal from about mid-December till mid-April; only the sides of the river freeze solid below Quebec, but navigation is held up from the end of November till the end of April (p. 424).

The shore waters and the harbours and narrows of the Great Lakes freeze, and a spell of on-shore winds widens and thickens the ice. The south half of Lake Michigan is open almost always, but the shores may have some ice; Green Bay, Wis., is closed from 8 December till 15 April on the average; the ports on the south shores of Lake Superior from the first week of December till the end of April (Sault Ste Marie from 4 December till 28 April); those on the south of Lakes Erie and Ontario, being farther south, from the middle of December till the first week in April.

To end this account of the winter temperature a comparison of the west and east coasts of North America, with each other and with the west and east coasts of Eurasia, is added:

West coast	*Lat. °N.*	*Mean temp. Jan.*	*East coast*	*Lat. °N.*	*Mean temp. Jan.*
North America					
Sitka	57·0	32	Hebron	58·2	−6
Victoria	48·5	39	St. John's (Nfld.)	47·5	24
Eureka	40·3	47	New York	40·7	31
San Diego	32·8	55	Savannah	32·0	53
Eurasia					
Portree	57·5	39	Ayan	56·5	−5
Brest	48·5	43	East Siberia	48·5	0
Oporto	41·2	47	Vladivostok	43·2	6
Mogador	31·5	57	Shanghai	31·5	38

The west coast of America is much warmer than the east in all latitudes, most so in the north. Sitka, Alaska, is never ice-bound, and is 38° warmer than Hebron, Labrador, from which icebergs are to be seen even at midsummer and continuous ice-pack during much of the year. Comparing the New World and the Old, on the west coast the Old is the warmer; the difference is small in the latitude of California, but considerable in the north, Portree being 7° warmer than Sitka. The difference is reversed and larger on the east coasts, largest in the latitude of New York, which is 25° warmer than Vladivostok. This is a result of the more constant monsoonal conditions in east Asia, where NW. winds from the cold interior seldom cease in winter; but in the east of America south winds are not infrequent as depressions approach from the west. Labrador is north of the usual cyclone tracks, and in its latitude America is rather colder than Asia.

SUMMER

The difference of temperature between south and north is much less in summer than in winter, partly because the decrease in the sun's altitude with increasing latitude is compensated by the greater length of the day. The mean temperature in June and July is similar over wide areas. In July the isotherms bend sharply poleward on the warm land; the 50° line has retreated almost to the Arctic coast, and in a considerable area the temperature exceeds 90°. The isotherms, which it must be remembered denote sea-level temperatures, run considerably farther north in the west than in the east, the western plateaux being unduly warm for their altitude since their cloudless skies offer less obstruction to insolation, so that the arid and semi-arid highlands are heated strongly in the long summer days. The following table, the temperatures in which are not reduced to sea-level, shows that Beowawe, Nevada, can be even warmer than Springfield, 4,000 feet lower; Austin also is remarkably warm for its altitude:

	Alt. feet	*Position*	*Mean temp. July*	*Abs. max.*
Beowawe	4,695	Humboldt R., Nevada	72	107
Austin	6,594	Plateau, Nevada	70	105
Springfield	609	Mississippi valley	78	106
St. Louis	568	,, ,,	79	110

The lowlands of Arizona, the Colorado and Mohave deserts, have temperatures comparable with those of the Sahara, under the blazing summer sun shining through the dry air. The highest record for the continent, 134°, occurred on 10 July 1913, in Death Valley, California, altitude —276 feet, where the July mean is 102°. The plateau is cooler:

	Alt. feet	*Mean temp. July*	*Abs. max.*
Mohawk Summit (Gila R.)	538	95	126
Tucson	2,390	85	111
Fort Grant	4,916	79	111

But the dry air helps to make the intense heat supportable and, moreover, the hot days are followed by cool nights on the higher plateaux; at Fort Grant the thermometer has been known to fall to 48° in July, at Tucson to 55°, but not below

60° at Mohawk Summit. Thus the range, both annual and diurnal, is large, the latter largest in the warmest months.

The summer isotherms near the west coast of the United States are noteworthy, showing an extraordinarily steep gradient; for some details see Chap. XXXVII.

British Columbia resembles California in the difference between cool coast and warm interior in summer. Vancouver Island has a July mean about 60°, being similar to the British Isles in summer as in winter; at Kamloops the July mean is 70°, and probably the sheltered valleys in the interior enjoy the warmest summers and the finest weather in Canada.

In the interior and east of the United States the isotherms are widely spaced, in contrast to those near the Pacific. The south-west is warmest, the neighbourhood of the Lakes and the coast of Maine coolest. In the Mississippi valley temperature is kept down by the cloudy skies; the High Plains enjoy clearer skies but the hot days are followed by cool nights. Representative data, arranged from south to north, are:

	Alt.	*Mean temp.*		*Absolute extremes,*	
	feet	*Jan.*	*July*	*min.*	*max.*
Key West	14	70	83	41	100
Galveston	69	54	83	8	101
San Antonio	701	53	84	4	107
Vicksburg	247	48	81	−1	104
Denver	5,272	30	72	−29	105
Omaha	1,103	22	77	−32	114
Chicago	824	24	73	−23	105
New York	314	31	74	−14	102
Halifax	99	24	65	−21	99
Montreal	187	14	70	−29	97
Winnipeg	760	−3	67	−35	100
Medicine Hat	2,144	12	69	−51	108
Vancouver	136	36	64	2	92
Fort Vermilion	950	−13	61	−78	98
Dawson	1,062	−21	60	−68	95
Hebron	49	−6	47	−42	87

Data for other stations are given on pages 458–60.

The summer temperature is lower than in the arid western States, but the high humidity, especially near the Gulf, is oppressive for white labour—one reason for the employment of negroes with its many social consequences.

The warmest part of the High Plains of Canada is the east

of Alberta. Farther east, in spite of decreasing altitude, the temperature is lower, Winnipeg being cooler than Medicine Hat in summer as in winter. Most stations in the Prairie Provinces have extremes well above 105° (Medicine Hat 108°, and even Fort Vermilion 98°). The summer heat, like the winter cold, is partly advective, air-masses drifting north after being warmed over the plains of the United States, partly of local origin in the long sunny days. But it can be cold as well as hot in summer in this region, for all of it except the extreme south has recorded frost in July, though the frost is never severe in high summer. In the middle and north of the Prairie Provinces snow has been known to interrupt the wheat harvest. However, the average frost-free period (p. 420) is about 90 days, from 60 days in the north to 110 days in the south (126 days, 15 May to 18 September, at Medicine Hat). At Fort Vermilion it is from 13 June to 17 August. The long northward loop of the 60° isotherm for July to the Arctic Circle (as in Siberia) is noteworthy; the actual temperatures are a few degrees lower than the sea-level isotherm indicates, and the summer is indeed short in the north, but even the far north has possibilities for the growth of potatoes and vegetables where the soil is suitable. The Great Lakes cool their neighbourhood appreciably; at Dubuque the July mean is 75° (absolute maximum 110°), at Milwaukee 70° (absolute maximum 105°).

The coasts of Labrador and Newfoundland are cool and foggy in summer. The 50° isotherm for July dips south almost to Newfoundland, and in an average year the temperature never reaches 80° on the Labrador coast and in the north of Quebec. Except July a month rarely passes without frost, and though south Labrador is in the latitude of Liverpool the summers are as cool as in the delta of the Mackenzie. The inclement weather is due to the cold Labrador Current which chills the inblowing winds and forms much fog. The interior enjoys less inhospitable conditions and parts bear coniferous forest, not very luxuriant but a pleasing contrast to the treeless coast. Similarly in Newfoundland the interior is more favoured (July mean about 62°), and has good coniferous forest and a little cultivation; but the main 60° isotherm passes well

south of the island, and marks the change from the bleak north to the Maritime Provinces, a region with warmer and longer summers, pastoral farming and the hardier cereals, potatoes, and apple-orchards.

The north coasts of the continent resemble Labrador, temperature being kept low, in spite of weeks of continuous daylight, by the many lakes and marshes, and the drifting ice which usually fills the adjoining channels except in August. Away from the coast the Mackenzie and Yukon basins near the Arctic Circle have warm but short summers; Dawson, which has known a winter minimum of $-68°$, once recorded 95° in July, making an extreme range of 163°—but a reading of 29° has been noted in July. The Yukon is much warmer in summer than the neighbourhood of Hudson Bay, and Fort Yukon has even recorded 100°. The absolute maximum at Aklavik is only 88°, but Fort Smith has recorded 103°.

The Canadian archipelago can hardly claim to have a summer, for the mean temperature of the warmest month is less than 50° in the south, and under 40° on the coasts in the north. Frost and snow are not rare, even in July, but on the other hand in spells of fine calm weather in June and July the sun shines throughout the 24 hours and the south-facing slopes are remarkably warm. The sea-ice only begins to break up in early July in most years, and is frozen solid again in September.

The isotherms loop northward between the Lakes and the Gulf of St. Lawrence; Montreal and Ottawa have a July mean of 70°, higher than the coast of the Atlantic, the shores of the Lakes, and even the Prairie Provinces. Peninsular Ontario is the most favoured part of the Dominion, thanks to its low latitude and the barrier against cold provided by the Lakes; it is truly the garden of Canada and produces temperate crops and fruits in abundance, including grapes, peaches, and apricots of high quality, in the Niagara Peninsula, and tobacco along Lake Erie, the warmth of late summer and autumn being an advantage. The snow is melted in March and spring comes on apace with rapidly rising temperature; June, July, August, and September are sunny months with hot days.

In summer Hudson Bay, with its cold water and much ice, chills its shores, which have means about 10° lower than

the Prairie Provinces; Moosonee at the south end of James Bay has the same mean temperature in July as Fort Good Hope on the Arctic Circle. The daily maxima are still more depressed, for the skies are more cloudy and fog is not rare; snow may fall round the north of the bay even in July. The sea-ice conditions depend chiefly on the direction and force of the wind which drives the ice; some years have little, in others navigation is almost stopped; the mean navigable period in Hudson Strait is August to October. Owing to the short cool summers the shores are bleak tundra. Spring is cold and late, but autumn often has dry, warm, sunny spells.

A notable feature during spells of fine weather in the dry country east of the Rockies, especially on the High Plains south of 45° N., is the occurrence of remarkably hot and dry winds, mostly in middle and late summer. Under a suitable pressure-gradient hot tropical air moves north, giving high temperatures to the whole region, but small areas, often narrow bands less than half a mile wide, may have an intense dry heat, temperatures rising even to 110°, which shrivels any vegetation exposed for long to it; the wind is usually S. or SW. It is an afternoon visitation, but may recur on several days. Three main explanations of this intensification of the normal heat of tropical air have been suggested: the baking of the hot, dry, sandy soil by a fierce summer sun, adiabatic heating of the upper air by subsidence, and, for winds from a westerly point, the usual föhn effect in the crossing of the Rockies. Probably all these explanations are valid, singly or together, in different cases.

The cold waves of winter have a summer parallel in the heat waves of the east of the United States south of 42° N.; they are spells of hot weather, many with moist tropical air brought by S. and SE. winds when an anticyclone lies off the east coast, and a low-pressure system over the Mississippi valley. The moist heat is enervating though the thermometer may not rise above 100°, and is responsible for heat-stroke and prostration, with many thousands of deaths in some years.[1] The higher temperatures of the western plateau are much easier to bear since the air is dry and exhilarating.

Frost Hazard. Almost all agricultural Canada and the north

[1] But many heat waves have sluggish continental air from the hot interior.

of the United States are handicapped by liability to severe frosts in late spring and early autumn which may do widespread damage to crops. Frost has occurred in every month of the year nearly everywhere except on the coast and in the sheltered valleys of the west, near the coasts of the Maritime Provinces and Newfoundland, which are frost-free in June,

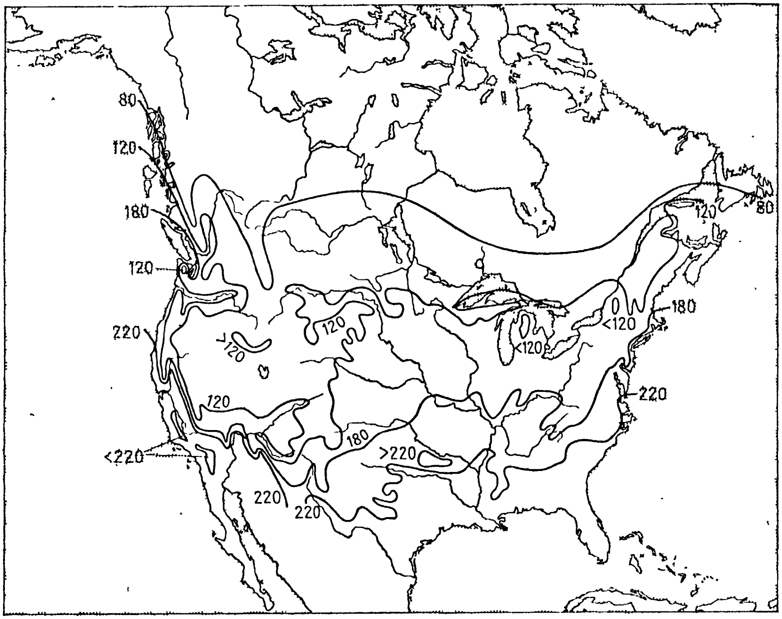


FIG. 128. Mean annual number of frost-free days (in U.S.A., days without 'killing-frost').

July, and August, and in the western prairies south of 50° N. where frost has never been recorded in July. At Winnipeg, favoured by the proximity of the lake, the absolute minimum in July is 35°, still well above freezing-point, but in the northern prairies frost may be severe in July; Fort Vermilion has recorded 20° in that month. Yet higher latitudes have less frost in summer thanks to the very long days, the thermometer never having been known to fall in July below 29° at Dawson (64° N.), 28° at Fort Good Hope (66° 25′ N.), 23° at Chipewyan.

Frost-free period. Fig. 128 shows the mean annual number of days without frost, an element of considerable significance for agriculture. Most favoured are the shores of the Gulf of Mexico

(even there, however, killing frosts are liable to occur every winter), the east coast south of Cape Hatteras and the west south of Cape Mendocino, with more than 220 days. The period decreases rapidly towards the north, notably on the plateau of the south-west, most of which has less than 120 days. Agricultural Canada has between 120 and 80 days, the lower

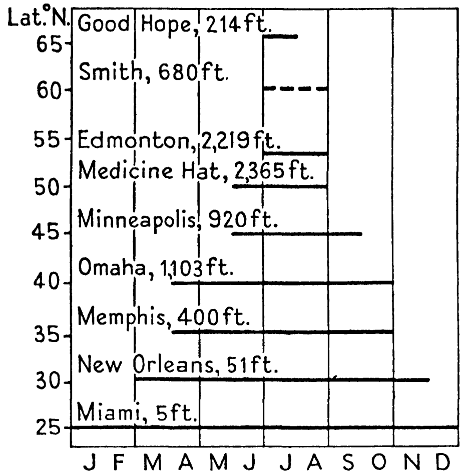


FIG. 129. Months with mean temperature over 60°.

Mackenzie only about 40. The advantage of the ocean coasts stands out clearly, particularly in the west. Fig. 129 gives another illustration of the duration of genial summer warmth from south to north.

Almost everywhere in North America autumn is warmer than spring (data in table below). Texas and the interior of British Columbia are exceptional in having April slightly warmer than October. That the coasts should have warmer autumns is not surprising; but it is noteworthy that even the plains in the far interior including Dakota have the same characteristic, and differ in this respect from the steppes of Asia. The explanation lies in the easy access in North America for oceanic influences.

MEAN TEMPERATURE

	Apr.	*Oct.*	*Diff. Oct.–Apr.*		*Apr.*	*Oct.*	*Diff. Oct.–Apr.*
Victoria . .	48	51	3	Bismarck, N. Dak. .	42	44	2
Kamloops .	50	48	−2	Kingston . .	41	49	8
Medicine Hat .	45	46	1	St. John's (Nfld.) .	36	46	10

Spring and autumn are only short transition periods, shortest in the interior and east of Canada, for as soon as the winter snows have melted temperature mounts rapidly with the lengthening days and clear skies to the full heat of summer, and autumn changes to winter almost as rapidly. But short as they are, spring and autumn (with late summer) present problems for the agriculturist; April and May can be abnormally wet or abnormally dry and windy; frost may cause serious damage in June and in August. These hazards are not less than the risk of unwelcome rain at harvest. The myriad lakes, rivers, swamps, and muskeg, on the Canadian Shield, have a very appreciable effect, holding back the spring while the ice is melting and the ground drying, and extending autumn while the water slowly cools. A spell of delightful weather, the 'Indian Summer', may be expected in autumn. The air is calm and hazy, the cloudless skies give warm peaceful days of subdued sunshine followed by crisp, frosty, starlit nights, and the bright colours of the autumn foliage from yellow to crimson and purple make a memorable picture. The Indian Summer is a feature especially in the interior and east of the continent.

'During the Indian Summer the air is calm. Glistening strings of gossamer stream across the landscape, all nearer objects are seen through a dreamy atmosphere filled with a rich golden haze, while the distance melts away in violet and purple. The surface of the river with its moving flood of silver reflects all objects and every colour with matchless fidelity, the harsher tones of the rocks, of the deep brown forests and of the yellow prairies appear so softened, the reflection of their pale tints is so perfect, and such a similarity of colour and shade pervades the earth, the air, and the water that all three seem blended together.'

Range of Temperature

The strong continentality of most of North America appears clearly in the large range of temperature from the warmest to the coldest month, in the contrast between the bright, sunny, warm or hot, long days of summer and the cold of winter—intense cold, though sometimes (not always) cold of that crisp kind, with calm dry air and cheerful sunshine in the short days, bright starlight in the long nights, reflected from

the sparkling frost and snow, in which the joy of active life is heightened. The mean annual range (Fig. 1, p. 14) increases rapidly from below 30° near the Gulf of Mexico and the Pacific to more than 40° in most of the interior. The north of the United States, including the Dakotas and Minnesota, has about 60°, and the middle and north-west of Canada above 70°. The east tends to share the extremes of the interior, all the east of Canada except the coasts having more than 55°, the coasts about 45°. The Gulf coast with about 22°, a small range for North America, contrasts strongly with the coast of South America opposite it which has only 4°.

The table below compares the July temperatures at stations on the west and east coasts of North America and Eurasia, the winters of which have been already considered (p. 414). The slow change from north to south on the west coasts as compared with the east is noticeable. The west coast of America is remarkably cool in the south owing to the California Current (compare Eureka and New York), but on the east coast the notably low temperatures are in the north, being an effect of the Labrador Current. America is cooler than Eurasia on most of the west coasts; the east coasts are similar in the south, but Labrador is much cooler than Siberia:

West coast	*Lat. °N.*	*Mean temp. July*	*East coast*	*Lat. °N.*	*Mean temp. July*
North America					
Sitka	57·0	55	Hebron	58·2	47
Victoria	48·5	60	St. John's (Nfld.)	47·5	59
Eureka	40·3	56	New York	40·7	74
San Diego	32·8	67	Savannah	32·0	81
Eurasia					
Portree	57·5	56	Ayan	56·5	54
Brest	48·5	64	East Siberia	48·5	63
Oporto	41·2	68	Vladivostok	43·2	65
Mogador	31·5	68	Shanghai	31·5	81

Ice

Ice causes serious loss and inconvenience in the east of North America in two ways, by jeopardizing shipping on the ocean east and south-east of Newfoundland, and by closing harbours to navigation. The former, being far beyond the coasts, cannot be fully described here; both icebergs and floes carried

south from high latitudes by the Labrador Current obstruct the shipping lanes in spring and summer, so that for safety they are shifted some 300 miles south-east in the period 15 January to 23 August. Some bergs may be carried into the Strait of Belle Isle by NE. winds between April and October, but most strand and break up before penetrating far, only a few reaching Amour Point.

The freezing-up of the ports is due to ice formed locally in the cold winters; the St. Lawrence River and Gulf are usually closed in the months December to April, and demand very careful navigation in November and May. The harbours and inlets farthest inland and containing the least saline water are naturally the first to freeze; before the end of December all are closed, but the intensity of the cold and the direction of the wind, as well as the use of ice-breakers, determine the date. The average date of closing of the port of Montreal is 9 December, and of reopening 18 April. The river between Montreal and Quebec is closed from 29 November (extreme dates 20 November and 14 December) till 22 April (extreme dates 29 March and 10 May.)

The Gulf below Quebec is rarely frozen over, but it is blocked by floes, which are often almost continuous, from early December till early June; the south has less ice, but navigation needs great caution. Thus the Gulf is closed in winter and dangerous for navigation in much of autumn and spring.

Cabot Strait does not freeze over, but contains heavy drift-ice in winter and spring, and for some weeks in most years continuous floes form a bridge right across; ordinary navigation is stopped from January to May. The narrow Strait of Belle Isle is closed from the beginning of December to late June.

Of the harbours on the ocean coasts, St. John's, Newfoundland, has some ice but is rarely frozen over and closed even for a week; the approaches may have floes driven in by E. winds between January and May, but can be navigated. Halifax is open except in the most severe winters; it has been closed only three times, for short periods, since 1850; the approaches are always navigable.

Thanks mainly to the very large tidal movement, the Bay of Fundy and its ports are free of ice. In the New England

States the conditions vary much. In mild winters the harbours remain open, in severe ones they freeze up for some days or weeks, and much drift-ice besets even the outer sounds. The harbours of Connecticut and New York are closed in some winters; in normal seasons Long Island Sound is navigable. The open coasts of New Jersey rarely have much ice, but the inlets are frozen in most winters, and even the entry to Chesapeake Bay is occasionally blocked.

Churchill, Manitoba, is open normally from mid-June till near the end of October, but most of Hudson Strait is ice-free only from late July to mid-October.

CHAPTER XXXIV

PRECIPITATION

Annual Amount

We shall first consider the yearly amount and afterwards the seasonal distribution (Figs. 130 and 131). The largest totals are on the Pacific littoral, where the westerlies from the warm ocean meet the mountains, and their ascent, together with the usual cyclonic activity of the westerlies, results in very copious condensation, massive low cloud and precipitation, the cloud as well as the precipitation providing useful moisture for the coniferous forests, especially in the neighbourhood of the international border, where the annual mean exceeds 100 inches. One of the highest means in the United States, 146 inches, is at Wynoochee Oxbow on the south slopes of the Olympian Mountains, Washington. In Canada the mean is even larger in the west of Vancouver Island (Henderson Lake, alt. 20 ft., west coast, has a mean of 262 inches; the total in 1931 was 319 inches) and on parts of the coast of British Columbia. South of Cape Mendocino it diminishes rapidly from 50 inches to 20 inches at San Francisco and 10 inches at San Diego. It is to be noted that the east slopes of the Coast Ranges as well as the west receive considerable precipitation, since they face the SE. winds in front of depressions approaching the coast. The close relation with relief is evident in the great longitudinal depression known in its various parts as the Strait of Georgia, Puget Sound, the Willamette valley, and the Great Valley of California, which has from 30 to 50 inches in British Columbia, 30

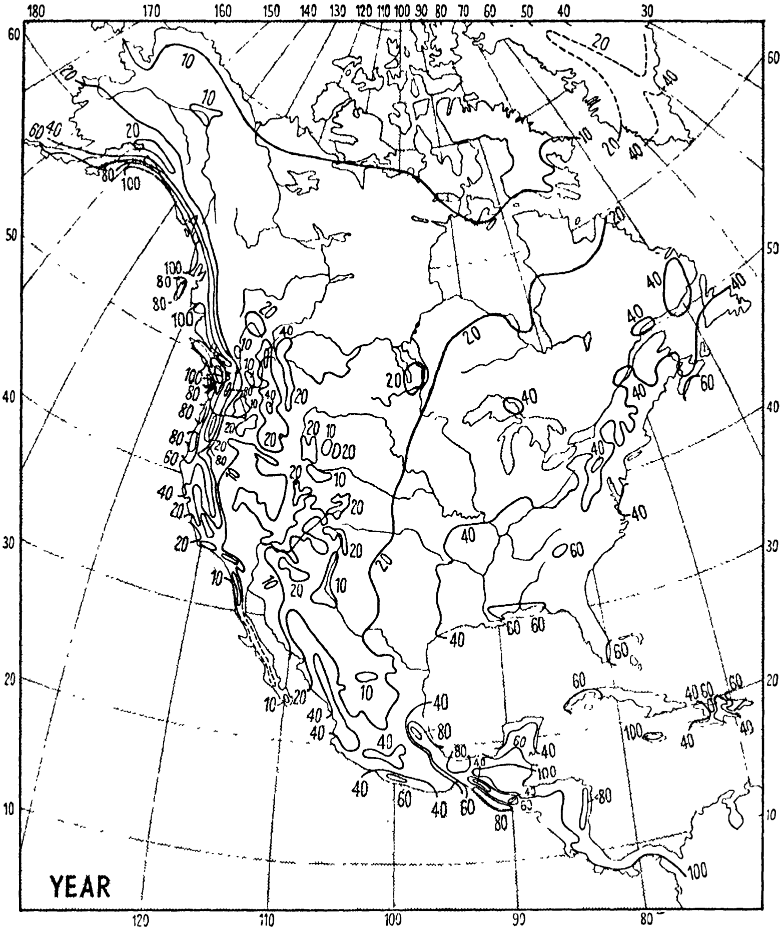


FIG. 130. Mean annual precipitation. (In Figs. 130 and 131 Canada based on most recent data, rest of maps on C. F. Brooks and others.)

to 40 inches in Washington and Oregon, 15 to 20 inches in the Sacramento valley, less than 10 and in places 5 inches in the valley of the San Joaquin. The amount is least not on the floor of the valley, but on the lower slopes of the east.

In the Cascade Range of British Columbia and the northern States, and the Sierra Nevada, the mean increases again, but only up to about 5,000 feet, above which it decreases ('inversion of rainfall'). The decrease continues on the lee slopes which,

unlike the east slopes of the Coast Ranges, get little rain from SE. winds. The intermont plateaux are very dry, since the double mountain-barrier on the west robs the westerlies of their vapour, and the Rocky Mountains on the east help, though in a less degree, to intensify the aridity. As in the west generally the precipitation of these plateaux is heaviest in the north; the interior of Washington and Oregon and the west of Idaho have 10 to 20 inches, but Nevada and the Colorado basin less than 10 inches since the westerlies are less strong and the enclosing mountains higher; moreover, the usual tendency to aridity in the sub-tropics asserts itself. The driest tract is the lower Colorado basin with annual means of 3 inches, 2 inches, and even 1 inch. As in most deserts, the rainfall is very variable; Yuma, Arizona, had less than 1 inch in 1899, but more than 11 inches in 1905, the average being 4 inches, falling on 13 days; Fort Apache, Arizona, 12 inches in 1903, 33 inches in 1905; Pinal Ranch, Arizona, 12 inches in 1903, 58 inches in 1905. This arid region has very dry air and remarkably clear skies, the mean sunshine, more than 3,500 hours a year, being the highest in the continent. The ranges which rise on the plateau have rather more rain, the Wasatch Range over 15 inches. The interior of British Columbia, in very remarkable contrast to the coast, has less than 10 inches in parts of the deep and sheltered valleys of the Fraser and Columbia rivers and their tributaries, the lowest official mean being 7·2 inches at Ashcroft; but the amount is less variable than in the Colorado basin; moreover, in the cooler and less dry air, evaporation is less active, and more of the rain is available for agriculture, which is helped, too, by the good irrigation facilities.

The precipitation increases on the Rockies, but surprisingly little for the altitude. A small area in British Columbia has over 50 inches, but in the United States most of the range has not much more than 25 inches. The heaviest precipitation seems to be on the heights, not on the lower slopes as in the Sierra Nevada; Pike's Peak, 14,111 feet, has 30 inches. The west of the Rockies has more than the east in the prevailing westerlies.

East of the Rockies the precipitation decreases in the steppes of the Great Plains, but is still considerably more than on the arid plateaux; it is least in north Montana and south Alberta

and Saskatchewan, where it falls to under 12 inches; the northern forest has more than 15 inches, the Barren Grounds, where the vapour-content of the cold air is low, less than 10

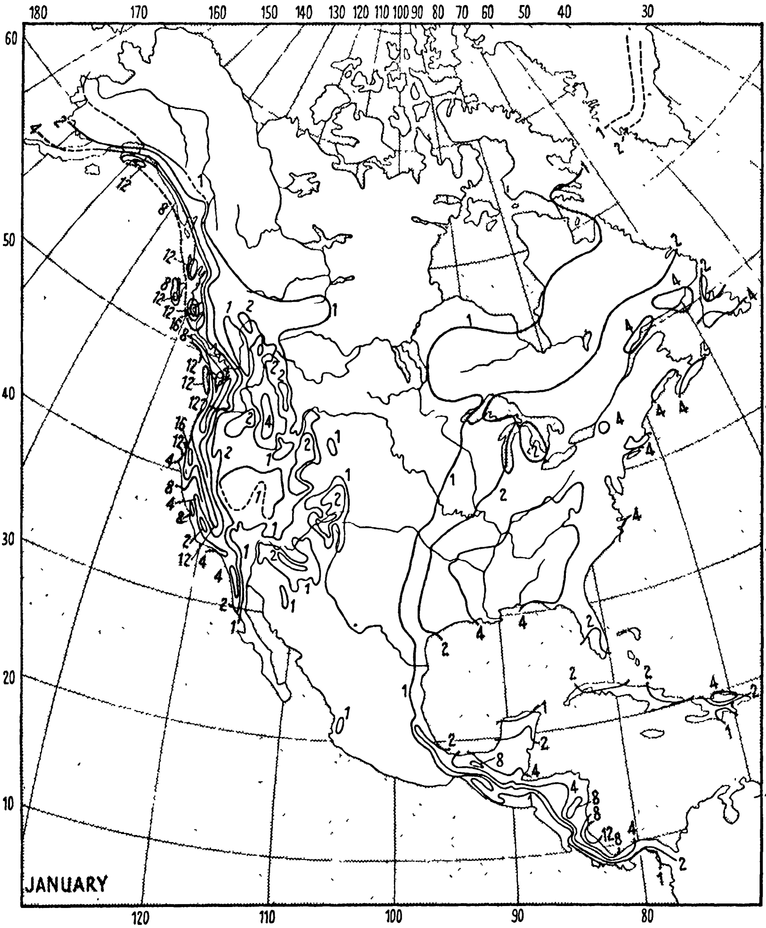


FIG. 131*a*. Mean monthly precipitation, January.

inches. Most of Canada east of the Rockies has below 110 days with precipitation, except the St. Lawrence basin, most of which has 150 to 170 days. In the United States the tract between the Rockies and 100° W. has means between 12 and 20 inches, very variable from year to year, and this is one of those marginal regions with just enough for agriculture in good years,

but far too little in bad, a series of which is disastrous. The crops fail, the dry surface soil is swept away by the high winds, and the infertile subsoil left bare; gigantic black clouds of

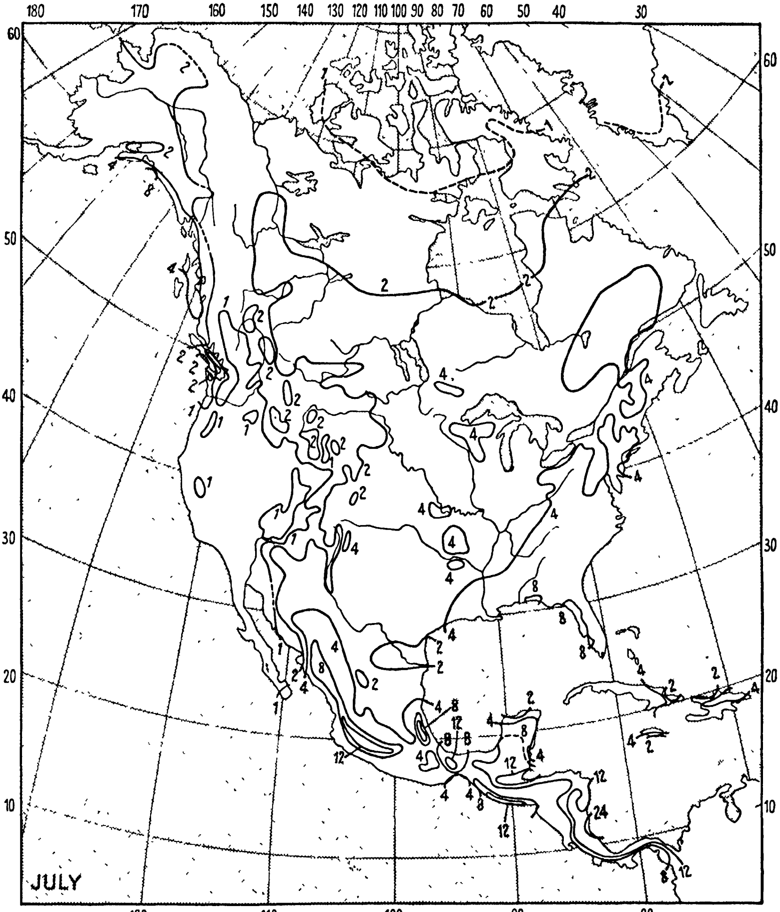


Fig. 131*b*. Mean monthly precipitation, July.

dust, 3 miles or more thick, were carried right across to the Atlantic seaboard in the drought of 1934. Most of the Middle West from Canada to Texas may be stricken at the same time.

From the 100th meridian precipitation increases towards the east and south. The south end of the Appalachians, which is within range of the moisture-bearing winds from both the

Gulf and the Atlantic, has more than 70 inches, the highest total for a large area in the United States excluding the Pacific coast. The coast of the Gulf exceeds 60 inches between New Orleans and Mobile, the heavy rainfall being associated with the hurricanes of late summer. The Great Lakes increase the precipitation to more than 30 inches, and the increase continues to over 50 in much of the Atlantic Provinces (about 45 inches in sheltered districts such as the Annapolis valley). Winter provides most of the increase, the vigorous cyclonic activity bringing moist tropical and cold continental air-masses into conflict; the precipitation is more reliable as well as more abundant than in the far interior.

The east and south-east States are liable to have torrential downpours, associated with thunderstorms or hurricanes in full intensity or in their later stages; the rain may exceed 8 inches in 24 hours, 10 inches in Georgia and Florida; New York has had 9·4 inches.

The interior and east of North America are favoured in rainfall above other continental interiors in the same latitudes, as a result of the advance far north of moist tropical air from the hot Gulf under the influence of the many pressure-irregularities. A great advantage for agriculture is that most of the precipitation is in summer.

SNOWFALL (Table, page 431)

Most of the east of the continent as well as the west has considerable precipitation in winter; on part of the east coast it exceeds that of summer, a peculiarity which will be referred to later. The winters are so cold that much of the precipitation north of 37° N. is in the form of snow; America is the snowiest of the continents. The Pacific coast and the lower slopes of the Coast Ranges are too warm for much (the coast north of Vancouver Island has snow on about 15 days, giving a total depth round 4 feet), but the other ranges of the western mountains in both Canada and the United States (except the extreme south) have a heavy snowfall of at least 16 feet a year, and many places much more; in large areas of the Sierra Nevada and the Cascades the mean exceeds 40 feet. The plateaux and the valleys have less, but the total rises again in the Selkirks to more than 30 feet, and on the Rockies in and north of

SNOWFALL

	Mean annual snowfall (inches)	*Months with nearly all the precipitation in the form of snow*	*Months with no appreciable snow*
Canada			
Goose Bay (Nfld.)	141	Nov.–Apr.	June–Sept.
St. John's (Nfld.)	101	None	June–Oct.
Halifax	77	,,	May–Oct.
Montreal	120	Dec.–Feb.	,,
Ottawa	96	Dec.–Mar.	,,
London	91	Dec.–Feb.	,,
Parry Sound	122	Dec.–Mar.	May–Sept.
Winnipeg	50	Nov.–Mar.	,,
Churchill	68	Nov.–Apr.	,,
Medicine Hat	31	Nov.–Mar.	May–Oct.
Edmonton	43	,,	May–Sept.
Beaverlodge	30	,,	,,
Atlin	53	,,	,,
Dawson City	55	,,	,,
Fort Good Hope	51	Oct.–Apr.	June–Sept.
Kamloops	34	Dec.–Feb.	Apr.–Oct.
Victoria	15	None	Mar.–Nov.
U.S.A.			
Boston, Mass.	44	None	May–Oct.
New York, N.Y.	33	,,	,,
Raleigh, N. Car.	8	,,	Apr.–Nov.
Erie, Penn.	54	,,	May–Sept.
Pittsburgh, Penn.	33	,,	May–Oct.
Alpena, Mich.	67	,,	,,
Cincinnati, Ohio	18	,,	,,
Chicago, Ill.	33	,,	May–Sept.
Duluth, Minn.	53	Jan.–Feb.	June–Sept.
St. Paul, Minn.	41	Jan.	May–Sept.
Memphis, Tenn.	7	None	Mar.–Nov.
Vicksburg, Miss.	2	,,	Mar.–Jan.
New Orleans, La.	0·3	,,	Jan.–Dec.
Bismarck, N. Dak.	34	Dec.–Feb.	June–Sept.
Rapid City, S. Dak.	34	,,	,,
North Platte, Neb.	26	,,	,,
Dodge City, Kans.	19	None	May–Oct.
Austin, Nev.	71	Nov.–Mar.	June–Sept.
Seattle, Wash.	14	None	May–Oct.
Portland, Ore.	14	,,	May–Nov.
San Francisco, Calif.	Trace	,,	Jan.–Dec.

Colorado to over 20 feet; its melting provides abundant water for irrigating the lower lands in summer. The south of Saskatchewan and North and South Dakota in the heart of the continent have a mean of 2 to 4 feet; during November to March snow falls on about 9 days a month. The amount increases

rapidly towards the east, and exceeds 4 feet everywhere east of Winnipeg; on the east shores of the Lakes it is especially heavy, amounting to over 10 feet in places. The St. Lawrence region also has much snow, most of it over 8 feet, 10 feet at Montreal, 10 feet on the Adirondacks, and the ground is covered deeply throughout the months December to March; most of the snow falls in the cold fronts of the many depressions. East Canada is the snowiest region of America outside the mountains, and the heavy winter fall is an outstanding feature of the climate. The coast of Maine has about 70 inches, of the other New England States 40 inches; most of New York State 60 inches, the north and west of Pennsylvania 40 inches, and the means rise to 100 inches near the Lakes. South of a line from the mouth of Chesapeake Bay to the south end of the Rockies the mean is less than 10 inches, and on the coasts of the Gulf snow is negligible. The Barren Grounds rarely have deep snow, and they may be swept almost bare by the strong winds, but in the sheltered forests snow often lies a few feet deep.

In most of Canada except the Pacific littoral, and in the north of the Middle West of the United States, rain is rare in at least part of the winter, all the precipitation being snow.

When the deep snows melt quickly over extensive areas the rivers soon run bank-full, and may flood, especially if the ground is frozen and impermeable. If heavy and continuous rains fall at the same time the floods are extensive and deep; great is the loss of life and very serious the damage to countryside and towns only too frequently in the north-eastern States. Rain itself, without snow, has been responsible for some of the worst floods. The region most liable to suffer is the low ground of the basin of the Ohio and the middle basin of the Mississippi, which receive the run-off of large areas of the north-eastern States with considerable mean precipitation even in winter and spring. Floods may occur in any month of the year, but the worst have been in late winter and spring; that of March 1936 in the north-eastern States resulted from heavy rain associated with unusual warmth and rapid melting of snow; one of the worst known, in the Ohio valley in January 1937, reached its height after 4 weeks of heavy rain with little intermission.

Thunderstorms

Widespread thunderstorms are few in Canada, but frequent in the middle, south, and east of the U.S.A. in summer, the mean number of days a year with thunder exceeding 90 in the north-west of Florida and 70 in the mountainous north of New Mexico; in most of the States east of the Rockies the average is about 50. The Pacific coasts have little thunder, the plateaux of the west and all the northern States about 30 days a year. Many of the storms are violent and do much damage, both by their excessive precipitation and, in the case of dry thunderstorms, by starting forest-fires. The hail that accompanies them does not usually reach the ground unmelted in the hot south or on the coasts, but is a serious hazard in early summer in the interior:

> In some parts of the Great Plains destructive hail-storms are so frequent that they have caused the abandonment of farms and sometimes of whole districts. It is not infrequent to see the fields so razed by hail that not a single plant is left alive (WEAVER and CLEMENTS).

Seasonal Distribution of Precipitation

The areas with similar distribution are shown in Fig. 132.

1. The Pacific type (Olympia, Fig. 133) has a strong winter maximum, December being the most rainy, July and August the least rainy, months. It includes the littoral, the Coast, and the Cascade Ranges, and extends to Alaska, but north of Vancouver Island the maximum comes rather earlier, at Bella Coola in November (Fig. 134), at Sitka in October. The type is similar to that found on the coasts of north-west Europe, but the much drier summers, a result of the great extension of the North Pacific anticyclone at that season, distinguish it. The rain is cyclonic, and in most of the region orographic also, and very abundant.

2. The California type (San Francisco and San Diego, Fig. 135), like the Pacific, is essentially coastal, but embraces also the Great Valley of California and the Sierra Nevada. The rain falls in winter, as farther north, but the rainless summer of 2 to 4 months is distinctive. This type corresponds to that of the Mediterranean lands in the Old World, but the autumn and

spring maxima which characterize much of that area are not found in California, where the rainfall increases steadily to its December maximum, and then decreases steadily to the rainless summer. The amount ranges from moderate to scanty.

3. The interior of British Columbia (Kamloops, Fig. 136)

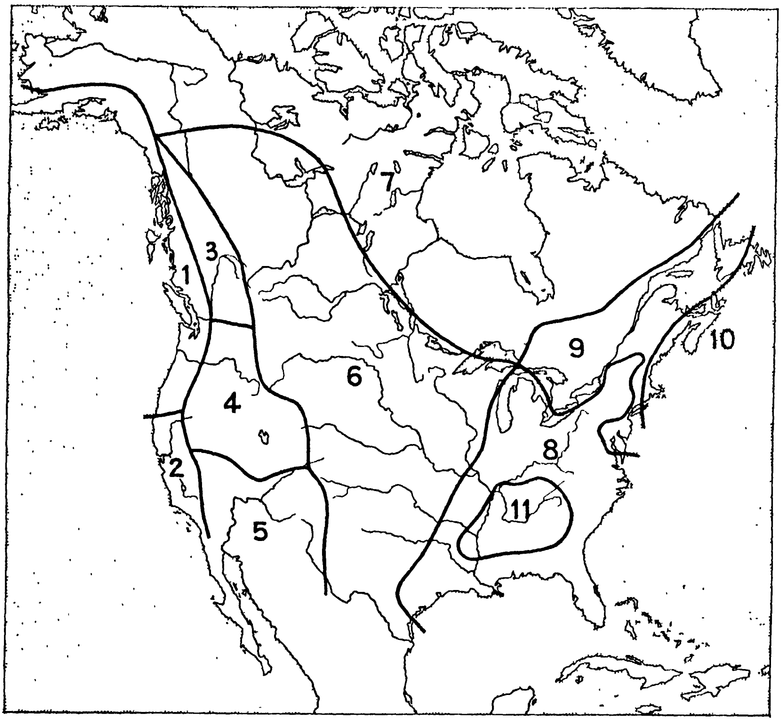


FIG. 132. Distribution of régimes of precipitation.

shows the transition from the Pacific coast with a strong winter maximum to the Plains with a summer maximum. The precipitation is fairly evenly distributed over the year, but spring is the driest season everywhere. In and north of the Thompson River valley the annual means average about 16 inches; of the seasons, summer has most (about 33 per cent.), and the winter and summer half-years have about equal amounts. The rainiest months are September (August or October in some places) and June.

South of the Thompson River the precipitation in the many valleys is about 12 inches in the west, increasing to 20 inches

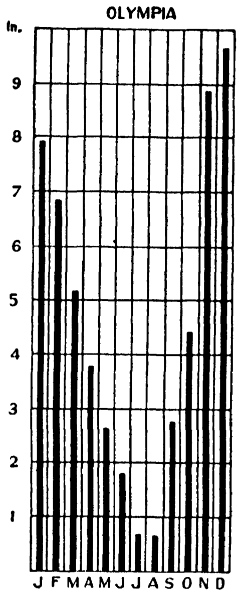


FIG. 133.

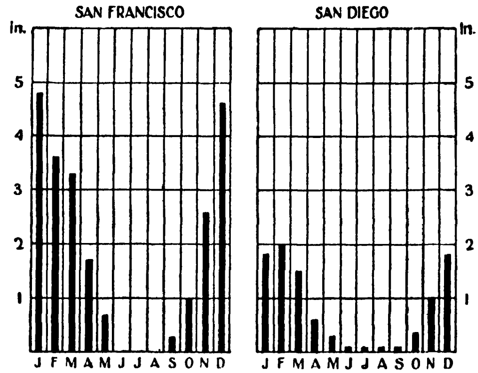


FIG. 135.

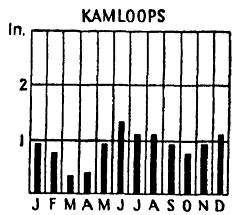


FIG. 136.

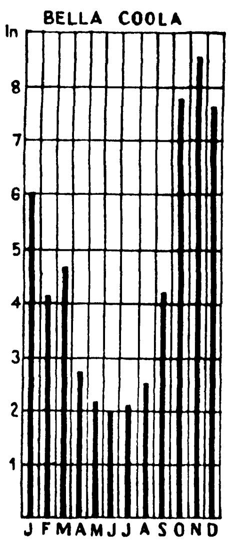


FIG. 134.

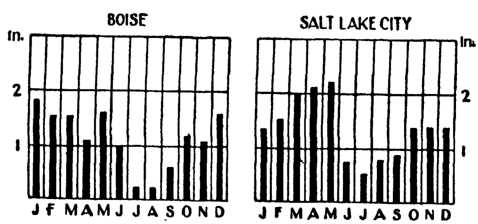


FIG. 137.

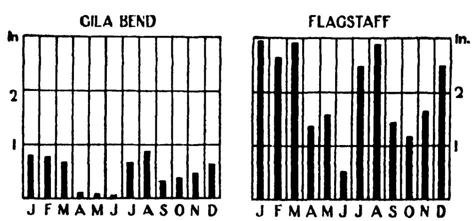


FIG. 138.

MEAN MONTHLY PRECIPITATION.

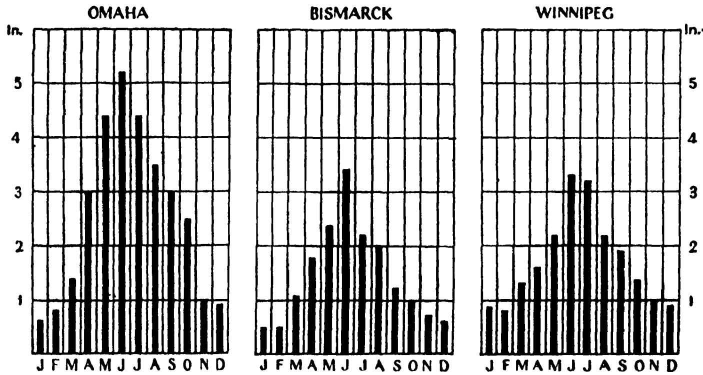


FIG. 139.

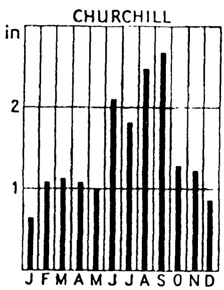


FIG. 140.

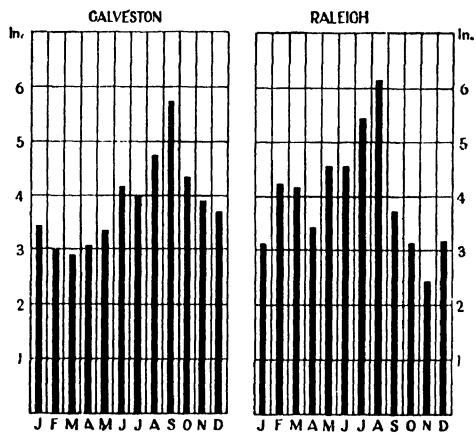


FIG. 141.

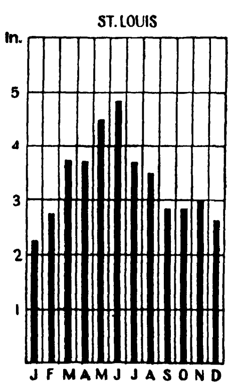


FIG. 142.

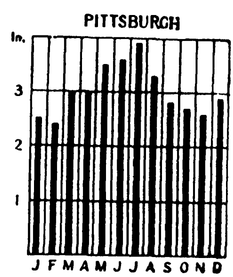


FIG. 143.

MEAN MONTHLY PRECIPITATION.

in the east; the mountains have much more (Glacier, 3,798 feet on the Selkirk Range, 53·7 inches). Winter is here the season with most (about 33 per cent.), and the winter half-year has more than the summer half; the winter excess is considerably larger on the mountains, according to the few records. Of the months December (or January) and June have most.

4. (Boisé and Salt Lake City, Fig. 137). South of the international frontier the coastal influence is stronger, and gives considerably more precipitation in the winter than in the summer half-year. December and January have most, and a secondary maximum is prominent everywhere in spring and early summer (compare 3), which, indeed, is the rainiest part of the year in the plains to the east. Late summer is dry. This 'Snake River type' extends east to the west foot of the Rockies.

5. The Arizona type (Gila Bend and Flagstaff, Fig. 138) includes the driest tracts of the continent. The régime shows two influences at work, the cyclonic activity of the Pacific giving a maximum in winter, and the intense local heating in late summer with convectional overturnings and showers in July and August, especially on the mountains. June is almost rainless. Both rains produce their own crops of flowers, the respective annuals dying and their seeds remaining dormant through the succeeding rains till their appropriate season returns.

6. This prevails with considerable uniformity over an enormous area, from the south of the United States to the forests of the north of Canada, and it may be named the Plains type (Omaha, Bismarck, and Winnipeg, Fig. 139). It has a strong periodicity; the early summer months have most precipitation, with a pronounced maximum in June. In the central area, including Alberta, Saskatchewan, and most of Manitoba, and in the United States the plains west of the line Duluth–El Paso and most of the adjacent Rockies, more than half is in the months May to August (in the south of Alberta 70 per cent.). North and South Dakota have about 80 per cent. of the whole in the summer half-year. This concentration of the rain in the agricultural months helps to compensate for the small total. Winter is a dry season, but no month is without precipitation, though December and January have less than half an inch

each, all of it in the form of snow, in the middle of the region. The heavy rain of early summer falls in instability showers, often with thunder; the prairies have a mean of about 4 thunderstorms a month in June, July, and August, and the damp south-east of the United States far more, thunder being heard on the average on about 70 days a year. The neighbourhood of Lake Superior is included in this region, but the lake modifies the régime; the maximum is in June as elsewhere, but the fall in the curve towards autumn is checked.

7. In the north and north-east of Canada the summer maximum is delayed till August or later, and autumn has much more precipitation than spring (Churchill, Fig. 140). The explanation may be found in the proximity of the sea, and in the fact that the ground is frozen hard and snow-covered in winter, so that the spring rise in temperature is delayed. In autumn, on the other hand, the extensive water-surfaces are still warm enough to provide vapour.

8. (Galveston and Raleigh, Fig. 141.) This Gulf type is distinguished by its late summer maximum, the rainfall increasing very noticeably in August and September; winter is much rainier than in the Plains, and rain is abundant in all seasons. Several cyclone tracks, much frequented all the year, lie in or near the region, notably on the Gulf of Mexico, off the Atlantic coast, and in the Mississippi valley, and the proximity of the warm sea favours heavy rain. The late summer maximum is in part due to the extremely heavy downpours associated with hurricanes, many of which enter the Gulf, whence they recurve towards the north-east (p. 519), working terrible havoc on any land they touch.

The Gulf type dominates the coast of the south Atlantic States as well as the Gulf of Mexico, and extends a considerable distance inland. The east of Missouri, part of Illinois, Indiana, Michigan, and Ohio approximate to the Plains type in that the maximum is in early summer (St. Louis, Fig. 142), but the winter precipitation classes them with the Gulf rather than with the Plains. Still farther north-east, in Pennsylvania and western New York, the influence of the Great Lakes, and perhaps of the Atlantic Ocean, is seen in the retardation of the maximum, which occurs later in summer, so that the régime again approaches that of the shores of the Gulf (Pittsburgh,

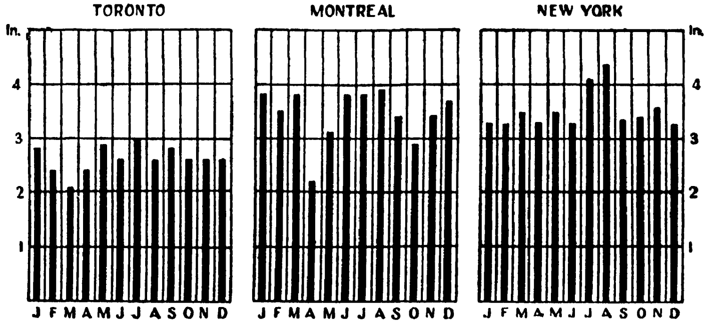


FIG. 144.

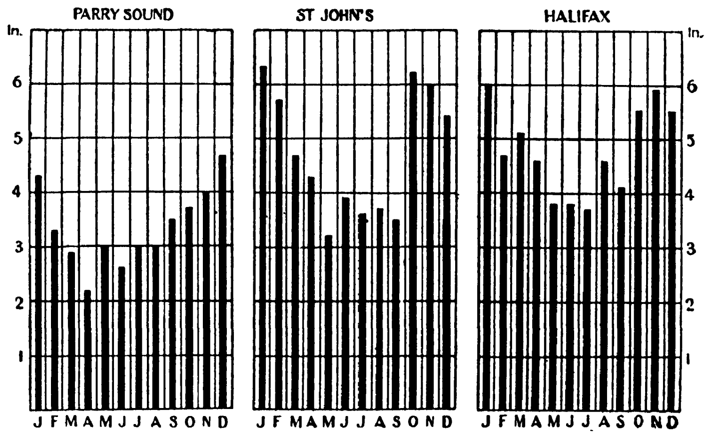


FIG. 145.

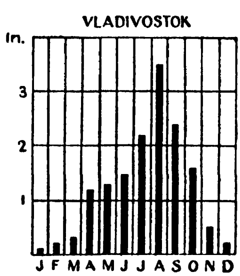


FIG. 146.

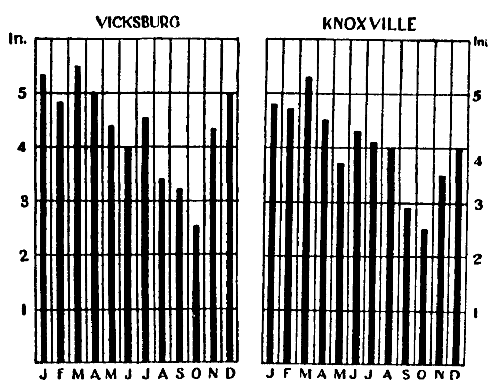


FIG. 147

MEAN MONTHLY PRECIPITATION.

Fig. 143); but the periodicity is less, and this feature indicates a transition to the St. Lawrence type.

Types 9 and 10 present a striking anomaly in the climatology of North America:

9. The St. Lawrence type (Toronto, Montreal, and New York, Fig. 144). The characteristic is the remarkable uniformity throughout the year. Most stations have a small maximum in late summer, and a slight minimum in spring, and the summer half-year has more precipitation than the winter half.

10. The Nova Scotia type (Parry Sound, St. John's, Halifax, Fig. 145) has its maximum in January, and considerably more precipitation in the winter than in the summer half-year. It covers the coasts from Newfoundland to Long Island and also a small tract along the east of Lake Huron.

Here, then, is the remarkable peculiarity of a pronounced winter maximum on the east coast of a continent in the temperate zone. Vladivostok (Fig. 146) in the same latitude on the east coast of Asia has the régime which might be considered more normal, a maximum in summer and a minimum in winter. The winter precipitation of the St. Lawrence basin is due primarily to the presence of the Great Lakes, the Gulf of St. Lawrence which extends far into the land, and the warm Gulf Stream. Owing to the humidity and warmth over these bodies of water depressions coming from the west have a pronounced tendency to make for the Lakes, and pass along them and the Gulf of St. Lawrence to the sea; many other depressions follow the warm water off the east coast of the United States. Hence the most frequented cyclone-tracks converge in this neighbourhood, the probability being that a depression which appears anywhere in the continent will leave it near the St. Lawrence. As cyclonic activity is specially vigorous in winter the precipitation is heavy at that season in spite of the low temperature and vapour-capacity of the air. It is interesting to notice how the St. Lawrence régime spreads north and south near the coast, especially south where it can be recognized as far as Washington. But a few miles inland continental influences assert themselves, and summer warmth and convection, seen in afternoon thunderstorms, override the winter cyclonic control.

11. The south Appalachian type resembles type 10 in having

more rain in the winter than in the summer half-year, but while the latter has a wet autumn and a dry spring the south Appalachians have least rain in autumn, and the early spring months are among the rainiest; the curve falls in May and rises to a secondary maximum in summer (Vicksburg and Knoxville, Fig. 147). On the whole this type has affinities with

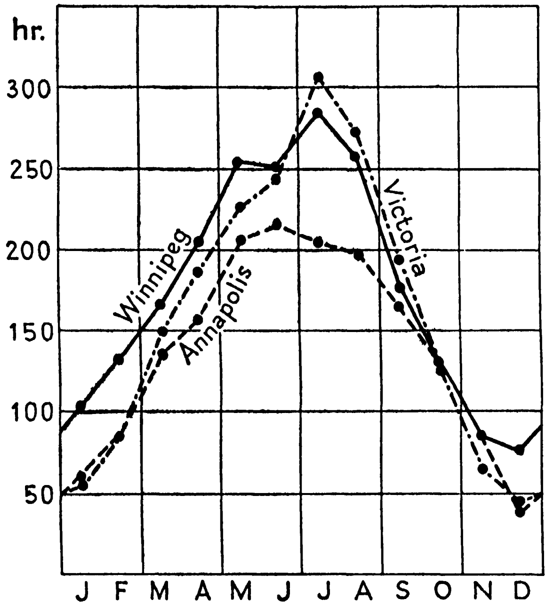


FIG. 148. Mean monthly sunshine.

the Gulf type, from which it differs chiefly in having no pronounced summer maximum.

CHAPTER XXXV

SUNSHINE. CLOUD. FOG

SUNSHINE

CANADA can claim to be a sunny land (but records are scanty in the north, which has no sunshine at all in winter). The means indicate both considerable regional uniformity and large seasonal range, summer with its long days being by far the sunniest season even in the Prairies which get most of their precipitation in that season (Fig. 148). The average in most of

the Dominion is about 2,000 hours a year, considerably more in the Prairies; the Maritime Provinces have least, less than 1,700 hours in places. The Pacific coast shows a large difference between summer and winter; the interior valleys of British Columbia have large totals as their low precipitation suggests. The high records of the Peace River valley are noteworthy.

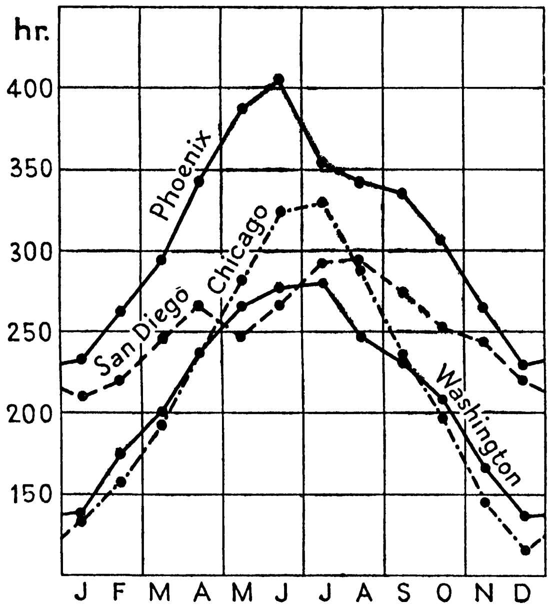


FIG. 149. Mean monthly sunshine.

The U.S.A. (Fig. 149) has more sunshine than Canada, as is natural in its lower latitude (an important consideration also if comparison is made with north-west Europe); but the records are not strictly comparable with those of other lands for two observational reasons, the use of a recorder of a different type, and the practice of making an addition to the trace for the time the morning and evening sun is visible but too weak to register itself, this 'low sun correction' being an eye-estimate by the observer; the result is that the records are lengthened by about half an hour a day. The sunniest region is the arid plateau of the south-west, with a mean annual total over large areas reaching 85 per cent. of the possible (3,900 hours a year at Yuma, truly a trade-wind desert figure). At the other

extreme the Pacific coast, the Great Lakes, and Maine have much less sunshine in winter than the average for the country, but even Portland, Ore., has 236 hours in winter, nearly half as much again as the midlands of England, and in summer its advantage is still greater. A comparison of the records at San Francisco and Sacramento shows the effect of the cool California Current on the former; the Great Valley has almost cloudless skies throughout summer.

Representative data are:

MEAN MONTHLY SUNSHINE (HOURS)

	Jan.	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*
Canada													
Annapolis	64	83	133	157	216	213	**221**	216	159	134	81	*46*	1,723
Ottawa	91	116	150	186	232	253	**273**	250	177	136	80	*72*	2,016
Winnipeg	100	131	168	204	247	252	**291**	263	177	127	86	*78*	2,124
Ft. Vermilion	62	126	167	188	226	234	**291**	240	174	138	91	73	2,010
Swift Current	92	123	164	209	261	273	**339**	294	202	162	111	*88*	2,318
Kamloops	64	105	176	231	250	260	**322**	286	214	151	69	*50*	2,178
Vancouver (city)	48	82	129	178	232	226	**287**	268	178	112	53	*39*	1,832
Victoria	69	97	154	206	271	280	**335**	304	209	136	78	*68*	2,207
U.S.A.													
Bismarck, N. Dak.	146	185	203	248	266	296	**343**	297	235	194	150	*130*	2,696
Chicago, Ill.	131	158	191	238	281	326	**330**	289	236	198	144	*115*	2,641
Cincinnati, Ohio	124	153	184	232	279	317	**324**	291	261	210	159	*116*	2,652
Denver, Colo.	196	218	231	248	268	312	**304**	280	265	233	202	*182*	2,939
El Paso, Texas	234	263	299	341	372	**383**	335	313	305	288	253	*216*	3,603
Erie, Pa.	67	111	163	206	258	**292**	290	260	210	148	73	*44*	2,126
New Orleans, La.	163	181	216	255	**282**	271	236	223	234	230	192	*136*	2,618
New York, N.Y.	147	191	216	246	273	**295**	289	261	241	209	164	*146*	2,680
Phoenix, Ariz.	234	262	296	344	389	**405**	354	342	336	308	266	*230*	3,766
Portland, Ore.	69	106	150	210	232	282	**328**	282	203	136	75	*61*	2,138
Sacramento, Calif.	*136*	187	246	312	356	405	**426**	395	353	279	194	*136*	3,432
St. Louis, Mo.	145	164	199	236	281	304	**314**	279	248	210	173	*130*	2,687
San Francisco, Calif.	*160*	181	233	275	301	**329**	305	261	270	241	186	166	2,910
Tampa, Fla.	190	224	262	293	**300**	280	262	259	254	226	215	*188*	2,953

CLOUD AMOUNT

The mean for the year is highest, over 7 tenths, on the outer coasts of British Columbia and Washington, but with a large seasonal range from 8 in winter to 5 in summer. It decreases along the coast of California from 6 to 3; the summer figure is raised by the frequent fogs. The plateaux and valleys of the western mountains have much clearer skies, with only 4 tenths cloud in British Columbia, 3 tenths in Nevada and Arizona. The middle and south-east of the continent has about 5 tenths, without much difference between summer and winter; but in the Prairies winter is cloudier than summer, e.g. 6 in November, 4 in July at Winnipeg, though the precipitation is heavier in

summer. Spells of drab overcast skies are a depressing feature of winter in the monotonous prairies. The St. Lawrence basin, the Atlantic Provinces, and the New England States, have about 6 tenths, again with little seasonal difference:

Mean Cloud
(Tenths)

	Cloudiest month	*Clearest month*	*Year*
Portland, Maine . . .	6	5	6
Boston, Mass. . . .	6	5	5
New York, N.Y. . . .	6	5	6

Fog

The well-known fogs of both the west and the east coasts are almost all sea-fogs resulting from the cooling of warm moist air below its dew-point as it passes over cooler water; the summer half-year is the foggy period. The sea-fogs are at times carried over the coasts, their intensity and frequency decreasing very rapidly inland so that the fog data from lightships and other vessels at sea, from coastal stations, and from the interior are very different.

On the west of the continent the cold Bering Sea and the Alaskan coast are very foggy in late spring and summer, when few days are clear.

Off British Columbia fog is most frequent in late summer (August and September have means of 10 days each with fog), and it often covers the entries to Juan de Fuca Strait (on about 46 days a year) and Queen Charlotte Strait in the morning, to break up in the heat of day. The inner sounds of British Columbia and their shores have most fog in spring; smoke from forest-fires in late summer in hot dry weather may also be a cause of very bad visibility. Land-fog spreads over the coastal waters in autumn (Victoria 8 days with fog in autumn, Seattle 16 days, Vancouver (city) 18 days; Vancouver, and Burrard Inlet on which it is situated, have very much industrial haze, thick as a fog especially in the winter half-year).

On the ocean adjacent to the U.S.A. the foggiest months are July, August, and September, and the fog often covers the coast; it pours into the Golden Gate nearly every afternoon in the months May to October. The foggiest area is between Cape Mendocino and the Golden Gate, but the fog-zone

extends south, with decreasing intensity, to Cape San Lucas. Characteristic data are given by Hurd (U.S.A. Hydrographic Office):

FOG, MEAN DURATION (HOURS)

	Jan.	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*
St. Georges Reef (42° N.)	18	36	33	25	42	96	167	**214**	147	110	49	*11*	949
C. Mendocino	118	114	88	*80*	91	119	180	**208**	187	173	128	85	1,572
Pt. Reyes	75	77	63	59	73	130	200	**227**	176	155	119	*57*	1,411
S. Luis Obispo	25	29	30	49	53	107	167	**175**	145	87	41	*19*	929
San Diego bay	14	15	8	6	5	8	*4*	6	13	**24**	19	12	134

Means (number of days a year with fog) at town stations are:

Vancouver (city), B.C.	37 days	(most in autumn and winter)
Portland (Ore.)	23 ,,	(,, autumn)
Eureka (Calif.)	51 ,,	(,, summer)
San Francisco (Calif.)	19 ,,	(,, autumn and winter)
S. Diego (Calif.)	22 ,,	(,, ,, ,,)
Manzanillo (Mexico)	0 ,,	

The winter fogs in large towns are reinforced by industrial haze.

The seas off the Atlantic Provinces and the north-east of the United States are the meeting-place of cold currents from the north with the tropical Gulf Stream, and are notoriously foggy, especially on the Banks south-east of Newfoundland where fog is recorded in ships' logs in about 30 per cent. of the watches, rising to 60 per cent. in June (Fig. 150); the foggiest area comes nearest to Newfoundland in May and June and then retreats south-east again. The fog is shallow, usually less than 500 feet deep (sometimes the mast-heads of ships project above it), and is normally associated with light winds (about 10 miles an hour) from SE. and S.

The coasts share the sea-fogs, which are brought inshore by light winds and clear at once when the wind comes off the land. The frequency decreases rapidly away from the sea, and even at the heads of estuaries fog is infrequent; records vary greatly within short distances. South and east coasts are much more foggy than sheltered west coasts; thus the west of Newfoundland has less fog than the east and south (St. John's 47 days, Port aux Basques 49 days, but Saint Georges on the west coast only 18 days); the north-east of Nova Scotia, and Northumberland Strait, have little (Charlottetown only 5 days a year), but Anticosti in the open Gulf of St. Lawrence has 25

days at South-west Point. The north shores of the Gulf have more than the south, and Belle Isle has as many as 103 days a year. In the inner reaches of the Gulf the frequency falls to only 10 days at Quebec and Montreal, where most of the fog is land-fog in autumn and winter. The frequency decreases northward and southward as well as westward, to 8 days at Hebron,

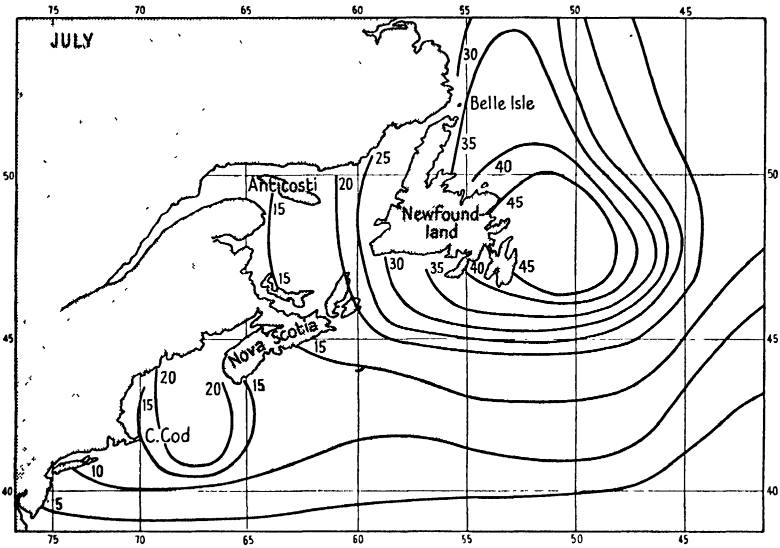


FIG. 150. Mean frequency of fog at sea in July (percentage of all observation hours).

Labrador, and about 12 days at Cape Hatteras; as elsewhere the sea-fogs are brought in by winds between E. and S.

Fog is a serious obstacle for navigation (the more serious as it covers the main shipping lanes between the United Kingdom and North America) in the months April to October, and particularly in June, July, and August, on the Banks and off the coast between Cabot Strait and Long Island; the coast itself is often involved. Some very exposed coastal stations in Maine and Massachusetts have over 1,000 hours a year, but, as in the Gulf of St. Lawrence, little sea-fog penetrates even a few miles inland; Portland, Maine, has fog on 23 days a year (most in summer), Boston on 13 (evenly spread over the year), New Haven on 11, and New York on 23 (the last two mostly land-fogs in winter):

MEAN NUMBER OF DAYS WITH FOG (i.e. visibility less than 1,100 yards)

	J.	*F.*	*M.*	*A.*	*M.*	*J.*	*J.*	*A.*	*S.*	*O.*	*N.*	*D.*	*Year*
Montreal .	2	2	1	1	<1	<1	<1	<1	1	1	1	2	11
St. John's .	2	3	3	6	6	4	5	4	3	4	4	3	47
Halifax . .	3	3	4	4	6	6	7	6	4	3	4	3	53
Portland, Maine	1	1	1	2	2	2	3	4	3	2	1	1	23
Boston . .	1	1	1	1	1	1	1	1	1	2	1	1	13
New York .	3	3	3	2	2	1	1	0	1	2	2	3	23

For comparison we give the mean duration in hours of 'thick weather', mainly fog and snow, at lighthouses and lightships:

MEAN DURATION (HOURS) OF THICK WEATHER

	Jan.	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*
Cape Race . .	164	143	114	154	308	286	429	256	186	149	116	125	2,430
West Quoddy Head	52	66	54	43	118	202	324	251	137	52	51	41	1,391
Nantucket Shoals lightship . . (41° 17′ N., 69° 58′ W.)	72	77	64	44	94	232	290	178	52	46	111	28	1,288
Ambrose Channel lightship . . (10 miles east of Sandy Hook)	158	151	114	73	63	150	128	163	75	91	215	125	1,506

At these points fog often lasts for 24 hours and sometimes for 4 days; once in July it persisted for 193 hours at Cape Race and for 262 hours at Belle Isle.

CHAPTER XXXVI

CLIMATIC REGIONS OF CANADA

IN the absence of strong relief except in the west of Canada the boundaries of regions cannot be precise. Fig. 151 shows a scheme as a basis for the more detailed division required for any purpose. The general conditions are given in previous chapters and only the outstanding characteristics are described here. Below are data (p. 448), additional to those already given, for representative stations in the regions as numbered.

A. *The Western mountains and coasts* (Regions 1–3)

1. Pacific littoral; warm rainy winters, very heavy precipitation on the coastal mountains, which have deep snow above 4,000 feet; warm sunny summers with little rain. Coasts ice-free, but rather foggy.

2. The interior uplands of British Columbia; precipitation

well distributed over the year (mostly snow in winter) but scanty in the deeply cut valleys, falling to 7 inches in places so that the natural vegetation is of a xerophytic type and includes cactus and sage-brush. Bright warm summers with long sunshine, cold crisp winters. Good irrigation from the mountains.

3. The Rockies, with a continental mountain climate. 3 (*a*)

		January			*July*			
		Mean daily			*Mean daily*			*Absolute*
		max.	*min.*	*range*	*max.*	*min.*	*range*	*extremes*
1.	Victoria	43	35	8	69	51	18	95, −2
	Prince Rupert	39	30	9	62	49	13	88, −6
2.	Kamloops	28	16	12	84	56	28	102, −31
3.	Atlin (2,240 ft., 100 miles W. of Rockies)	9	−4	13	64	43	21	85, −50
	Banff (4,521 ft.)	22	4	18	73	43	30	93, −60
	Lake Louise (5,032 ft.)	17	−8	25	71	36	35	94 −63
4.	Halifax	32	15	17	74	55	19	99, −21
	Annapolis	32	16	16	74	54	20	89, −13
	Quebec	18	2	16	76	57	19	96, −34
5.	St. John's (Nfld.)	29	18	11	68	51	17	92, −21
6.	Parry Sound	25	6	19	78	57	21	100, −39
	London	29	15	14	81	58	23	106, −27
7.	Montreal	21	6	15	78	61	17	97, −29
	Ottawa	21	3	18	81	58	23	99, −35
	Sudbury	20	−1	21	78	54	24	102 45
8.	Winnipeg	7	−13	20	79	55	24	100, −35
	Swift Current	17	−2	19	81	52	29	107, −54
	Calgary	24	2	22	76	47	29	97, −49
9.	Medicine Hat	22	2	20	84	55	29	108, −51
10.	Fort Vermilion	−1	−24	23	75	47	28	98, −76
	Fort Good Hope	−14	−33	−19	72	47	25	95, −79
11.	Churchill	−11	−27	16	65	43	22	96, −57
12.	Dawson City	−14	−28	14	73	47	26	95, −68
13.	Coppermine	−12	−26	14	58	42	16	87, −54
	Hebron	1	−12	13	56	38	18	87, −42
	Goose Bay	8	−8	16	71	52	19	100, −32

has long and extremely cold winters, short summers, warm, however, for the latitude; 3 (*b*), very cold winters, with much snow on windward slopes; 3 (*c*), less cold winters (allowance being made for greater altitude) and warmer summers.

B. *The Maritime Provinces and the east interior* (Regions 4–7)

4. Though coastal, has an extreme climate with warm summers for the latitude (New Brunswick 3 months with means over 60°), and unpleasantly cold and often bleak winters (mean January temperature about 20°), with strong winds and changeable weather. Mean annual precipitation more than 40 inches, remarkably evenly distributed over the year, abundant

for forests and agriculture, fruits, vegetables, and potatoes; in the period November to March all falls as snow. Ports ice-bound in winter except those on the ocean coast, and rivers frozen. The mean temperature at Quebec in all months is about 3° less than at Montreal, 150 miles up the river. The Height of Land has very cold winters (abs. minimum at Iroquois Falls, Ont., 850 ft., —73°). At the other extreme is the south and west

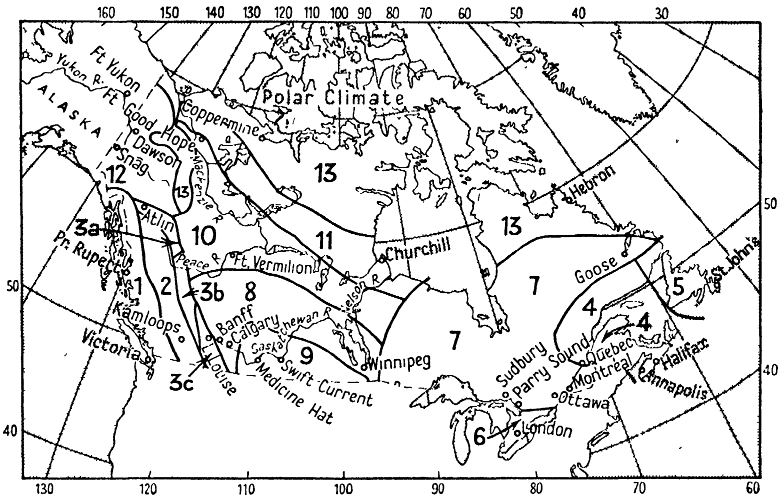


FIG. 151. Major climatic regions.

of the peninsula of Nova Scotia, including the Annapolis valley, which has shorter and less cold winters, good precipitation, but less snow than the lands to the west.

5. Newfoundland, distinguished from 4 by its cool summers (1 month only with mean about 60°), foggy coasts, icy seas.

6. Peninsular Ontario has in some respects the most favoured climate in the Dominion thanks to its low latitude and the influence of the Lakes; it has the longest frost-free period except the Pacific coast; warm humid summers with hot sunny days (107° has been recorded), long warm autumns.

7, transitional between 4 and 8; the mean annual isohyet of 20 inches forms a convenient boundary on the west.

C. *Central* (Regions 8–10).

8 has a strongly continental climate; winters very cold (January means—5° to 12°, temperature rarely rising above 32°),

but dry and sunny, with about 40 inches of snow (very variable, however, from year to year) and no rain. Summers warm (July mean 62° to 67° but frost is not unknown); very large range of temperature. Mean annual precipitation under 20 inches, 70 per cent. of it in the summer half-year.

9. Still more continental than 8; hot summers (July mean nearly 70°); precipitation in parts under 12 inches and insufficient for agriculture, the natural vegetation including cactus and sage-brush (artemisia, spp.) which spread from their main habitat in the arid south-west of the United States. Some snow in winter, but the ground is often bare.

10 diverges from 8 in the other direction, having cooler summers, which, however, are still remarkably warm for the latitude (July mean about 60°, rather under 60° in the extreme north) thanks to the long days, continental position, and shelter by the Rockies. Winters long and intensely cold. Mean annual precipitation 15 inches in the south, 10 inches in the north, nearly all in summer but some snow in winter. The warm summer is short (only 5 months have means above 32°, July about 60°), but long enough on good soils for some crops, including wheat in the Peace River lands where it is sown in the second half of May and reaped in the middle of August; these warm sunny months are in marked contrast to the bleak chilly summers of region 11 in the same latitudes.

D. *The bleak north*, distinguished by the cool, inhospitable, summers (Regions 11 to 14).

11. Mean temperature of the warmest month above 50° but under 57°; winters intensely cold as in 10. Annual precipitation 10 to 15 inches. The vegetation consists largely of small trees, conifers and poplars; great areas of lake and muskeg.

12. The Yukon has an extreme climate, mean annual range about 70°. The winters are very cold with little daylight, but the air is dry and the sky clear except in cyclonic weather; −78° has been recorded at Fort Yukon, and −81° at Snag Airport on the Alaska–Yukon border in February 1947, when interesting effects of the intense cold were noted—the breath froze immediately with a hissing sound and remained motionless in long trails for several minutes, audibility was uncannily super-normal, ordinary sounds from an Indian village 3 miles

distant being heard plainly. Spring is very short; early April is still winter, but most of the snow in the valley is melted by May, and the Yukon River is navigable from June till the end of September. Despite the high latitude 5 months have mean temperatures above 40°; 85° is exceeded in most years, and readings up to 100° have been registered; but the climate is treacherous and frost may occur even in July. Abundant sunshine in summer. Mean annual precipitation only about 10 inches, most in summer, very little in spring; mean snowfall on the low ground 40 to 60 inches. Grain and vegetables are grown with fair success; forests extend up to 4,500 feet.

13, the Barren Grounds, clothed mainly with low woody shrubs and moss. Summer is often a cool and cheerless season despite long days, the July mean being less than about 50°, with much cloud and fog; temperature may fall below −50° in winter. Precipitation is scanty but frequent, and snow falls even in summer. Winds are moderate to strong on the coasts, which are ice-bound except in July and August in some years. The highlands over 6,000 feet west of the lower Mackenzie River are included, but most of the Barrens is low ground. The archipelago of great islands on the north is too cold, particularly in summer (July mean under 45°) to be included; its climate is polar. The channels between the islands are completely frozen most of the year, but clear of ice in places in late summer, the ice being very variable from year to year.

CHAPTER XXXVII

CALIFORNIA

CLIMATIC REGIONS

California has established its claim to have the most attractive climate, over the year as a whole, of America, and the residential population has grown rapidly; the climate and topography of the Great Interior Valley are uncommonly well suited for orchards and other delicate agriculture; citrus fruits flourish almost to lat. 40° N. But this large State includes very

different climates; neither the high mountains nor the deserts of the south-east can share the praises of the coasts; a general sketch of the topography is a necessary preliminary to a study of the climates.

The coasts are well sheltered by the western mountains and

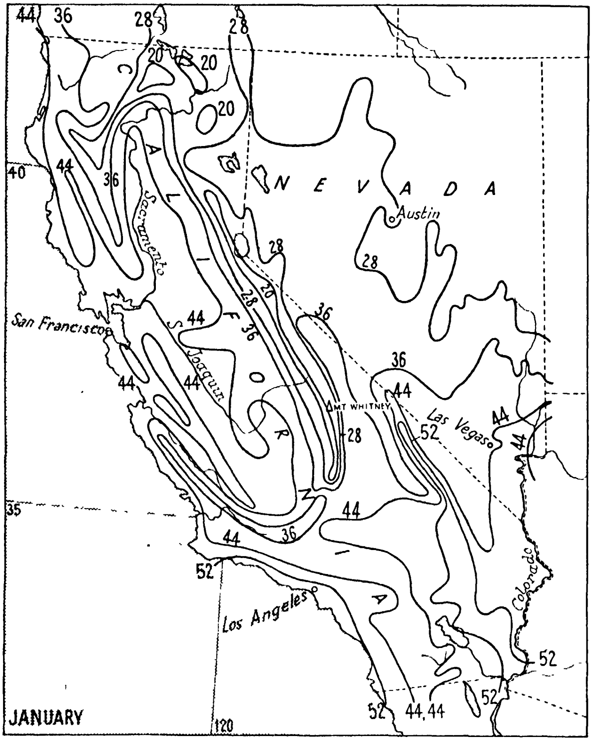


FIG. 152*a*. Mean isotherms, January (approximate values, not reduced to sea-level). Based on charts in *Climate and Man.* (United States Department of Agriculture, 1941.)

plateaux from the continental extremes of the interior; cold waves and blizzards are hardly known, tornadoes and thunderstorms are rare and seldom of violence. The coastal strip is narrow, less than 10 miles wide except in the lowland which includes Los Angeles; the shores are washed by the cool California Current which chills the air, so that fog is frequent in spring and summer.

East of the two Coast Ranges, which rise from the littoral to

some 5,000 feet, lies the Great Valley, a flat-bottomed depression 400 miles long, 50 miles broad, and less than 200 feet above sea-level, which is drained by the Sacramento River in the north and the San Joaquin in the south; it is walled in on the east by the lofty Sierra Nevada rising to over 14,000

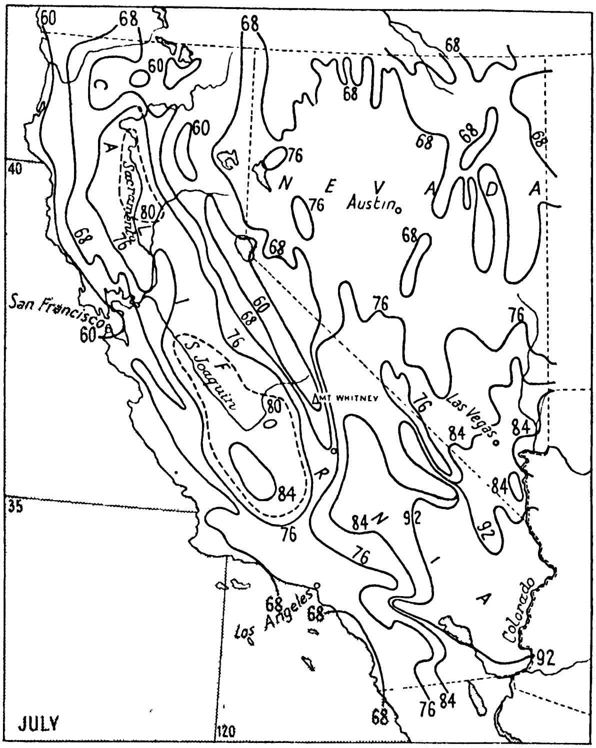


FIG. 152*b*. Mean isotherms, July (approximate values, not reduced to sea-level). Based on charts in *Climate and Man*. (United States Department of Agriculture, 1941.)

feet. The Coast Ranges shut out the cooling sea influence except opposite the Golden Gate and other minor gaps.

The Sierra Nevada, an unbroken rampart rising steeply from the valley, culminates in the perpetual snows of Mount Whitney, 14,495 feet. This great block of highland slopes less steeply eastward and south-eastward to the Mohave and Colorado deserts, which have an altitude of 3,000 feet in the north, fall to sea-level in the south-east, and below sea-level in the

depressions of Death valley (—276 feet) and Salton Sea, where the aridity and heat in summer are overpowering.

The climatic divisions follow the topography in trending north–south, not east–west, as is suggested by the isotherms (Fig. 152).

1. The coasts, with the cool ocean to windward, have a maritime climate, warm winter, cool to chilly spring and summer, small range of temperature (9° in the north, 15° in the south, but increasing fast as soon as the actual coast is left), much fog in the months June to November. The interior, however, asserts itself in the hot, dry, E. winds which occasionally blow in summer. Fog is persistent in spring and summer for 50 miles seaward, with a depth of about 1,500 feet; it dissolves before it can penetrate far inland. The fog-belt, however, is a feature on the Coast Ranges, and provides copious moisture for the redwood trees, the leaves of which are adapted to collect it.

The littoral may be conveniently divided by the parallel of 35° N. into a northern section, distinguished mainly by its very cool and damp, though rainless, summers (mean July temperature less than 60°), and a southern with warmer and more pleasant summers (the July mean exceeding 65°), and considerably warmer winters (January mean over 50°). In both sections most of the rain is in winter from November to March; the annual mean is from 50 to 20 inches in the north, 15 inches in the south.

This is the residential and holiday region; to its climatic charms are added beauties of topography and vegetation. The winter is cool or mild but not cold, and the coast is indeed a paradise in comparison with the interior of the continent with its many forms of intense cold. Frost does occur, but rarely in the north, very rarely in the south, and it is never severe or of long duration. True, winter is the rainy season, but the amount of rain is small, and the number of hours and days with rain is less than even the small amount might suggest. The mean cloud-amount is 5 tenths or less; bright sunshine and blue skies leave lasting memories. A drawback is the fog, which often lies off the coast, and spreads over the land on an average 2 or 3 days a month, changing to low stratus cloud.

Unlike the corresponding regions in other continents the coast is favoured in summer as well as in winter. The sea-

breeze tempers the heat and keeps the air comfortably humid, giving a mean July temperature at Eureka 56°, at San Francisco 59° (rather too cool), at Los Angeles, 10 miles inland, 71° and at San Diego 67°; Point Reyes has only 54°, being a cape projecting into the cool current. Maxima occasionally exceed 110°, but rarely, and only where the coast lies close under a south-facing slope. Thunderstorms are very rare. A drawback is the liability to hot dry winds, 'Santa Ana', which blow from the deserts in the east, often with force; they are more frequent in winter than in summer, and are dry (relative humidity may fall below 5 per cent. in the south), hot, and dusty:

> On the coast they are hot and are skin-drying, lip-cracking, unpleasant visitants. In places they pierce window-panes with little round holes as if drilled by the coarse gravel they carry like a dose of small shot. If they come in spring after the first blooms form, both the bloom and the young fruit drop off the trees after a short time (*Climatological Data of the United States*).

These winds are of the föhn type, and they often blow down from the desert through the Cajon Pass (4,265 feet) to the Los Angeles district.

The neighbourhood of the Golden Gate has several interesting features as a result of the topography. At San Francisco late September is the warmest time. The long retardation of the maximum is explained by the fact that in summer the interior of California is very hot, and a strong sea-breeze sets in through the Golden Gate, bringing the low temperatures of the California Current (the cooler owing to the upwelling water in summer). But in the beginning of autumn the interior is cooling, the sea-breeze weakens, and the coastal waters are no longer abnormally cool, so that although the sun has already retired to the equator September is the warmest month.

The summit of Mount Tamalpais, which overlooks San Francisco from beyond the Golden Gate, is much warmer than that town in summer, for despite its altitude, 2,375 feet, the July mean is 70° (Fig. 153). Its advantage is due to its rising into bright sunshine; it looks down on to the dazzling top of the fog-layer which so often shrouds the coast, and stands well above the cool surface air that comes in from the California Current. In winter, however, when sea-fog is less frequent

and temperature depends less on the direct rays of the sun, Mount Tamalpais is cooler than San Francisco. The mean annual range of temperature is 25° at the former station, only 11° at the latter.

The Mediterranean of the Old World is recalled both by the rainfall and the temperature of the California coasts. The contrast between the cool Atlantic coast and the hot middle and east of the Mediterranean region is repeated in an exaggerated form, for the coast of California is cooler, damper, and foggier

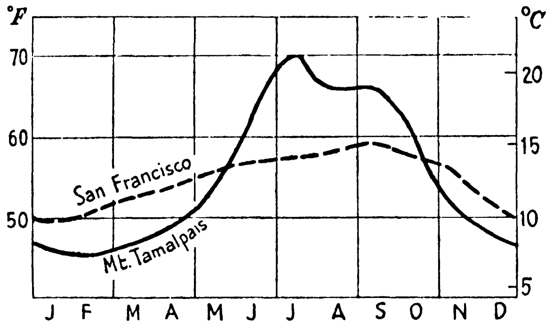


FIG. 153. Mean temperatures.

than Portugal, and the Great Valley even hotter and more sunny than the south of Italy and Greece, the summers being remarkably dry and cloudless. This is partly explained by the lower latitude of California, partly by the difference in the topography, the Great Valley being continental, Greece and Italy peninsular. The closest parallel to the cool foggy Californian coast is found in Morocco, which, however, is warmer. Gibraltar is about 14° warmer in July than San Francisco in the same latitude.

2. The Great Valley has a more continental climate, a result of the topography, the mountain-shelter from the ocean, and the latitude. Winter is cool, and frosts (on 125 nights a year in the north, 85 in the south) are serious for agriculture on the low ground in winter and spring, minima falling below 18°. Fog is fairly frequent. Summer is hot (July mean 83° at Bakersfield in the south, 82° at Red Bluff in the north), with maxima exceeding 115°, in great contrast to the cool coast. The difference between coast and interior, about 75

miles apart, is as large as between Scotland and north Africa. But the strong NW. wind finds its way through the Golden Gate into the Great Valley, and spreads north and south up the Sacramento and the San Joaquin; its effect can be clearly traced, the July mean being 74° at Stockton opposite the opening, and increasing north and south to over 80°. On the Sierra Nevada temperature rises at first, in spite of altitude, with increasing distance from the sea; as the slope steepens the reduction by altitude asserts itself more strongly, but an ascent to 7,000 feet is necessary to reach the temperature of San Francisco.

Precipitation is scanty, less than 10 inches a year in the south, most of it in winter as on the coast, but the Sierra Nevada provides excellent irrigation. Skies are bright in winter, almost cloudless in summer.

Apricots, cherries, almonds, walnuts, peaches, pears, plums, grapes, figs, and olives are grown most successfully, and citrus fruits of all kinds flourish in the foot-hills. This is the only section of the United States in which raisin making is carried on (ibid.).

But hot, föhn, winds sometimes descend from the plateau and afflict the north of the Valley, their dry heat being most damaging to agriculture in late spring; they increase the risk of forest-fires and other conflagrations.

3. The Sierra Nevada has a series of altitude climates, temperature decreasing upward to the eternal snows of Mount Whitney itself. The name of the mountains recalls a main feature of the climate, the very abundant snowfall on the western slopes—the most abundant of the continent, the annual mean attaining 450 inches at Tamarack, 8,000 feet, where in one winter the total was 884 inches. It provides valuable irrigation-water for the Great Valley.

4. The deserts of the south-east have the usual climates of trade-wind deserts, modified by the considerable altitude, about 3,000 feet, in the north, and by the depressions in the south. For some details see pages 409 and 415.

CLIMATIC MEANS

TEMPERATURE (°F.)

Canada

	Alt. feet	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*	*Range*
Coppermine, NWT.	13	*−19*	−19	−16	0	22	38	**50**	46	36	18	−6	−16	11	69
Fort Good Hope, NWT.	214	*−24*	−19	−10	14	38	54	**59**	56	40	21	−6	−20	17	83
Mould Bay,[1] NWT.	52	*−31*	−31	−21	−10	12	30	**38**	35	20	−1	−15	−30	0	70
Dawson City, Yukon	1,062	*−21*	−12	4	29	46	57	**60**	55	42	26	1	−14	23	81
Atlin, B.C.	2,240	*2*	8	19	32	43	51	**54**	53	46	36	24	12	32	52
Prince Rupert, B.C.	170	*35*	36	39	44	48	53	56	**58**	54	47	42	36	46	23
Victoria, B.C.	228	*39*	40	44	48	53	57	**60**	60	56	51	45	41	50	21
Vancouver, B.C.	45	*36*	39	43	48	54	60	**64**	63	57	50	43	39	49	28
Lillooet, B.C.	840	*26*	31	42	51	59	66	**71**	70	61	50	39	28	50	45
Prince George, B.C.	1,870	*13*	18	30	40	49	56	**60**	59	50	41	29	16	38	47
Fort Vermilion, Alta.	950	*−13*	−5	8	31	48	56	**61**	57	46	32	10	−6	27	74
Edmonton, Alta.	2,219	*6*	11	23	40	51	58	**62**	59	50	41	25	13	37	56
Banff, Alta.	4,521	*13*	17	25	36	45	52	**58**	56	47	39	25	17	36	45
Calgary, Alta.	3,540	*13*	17	26	40	50	56	**62**	60	51	42	28	19	38	49
Medicine Hat, Alta.	2,144	*12*	15	28	45	55	63	**69**	67	56	46	28	19	42	57
Winnipeg, Man.	760	*−3*	2	16	38	52	62	**67**	64	54	41	22	6	35	70
Churchill, Man.	44	*−19*	−17	−6	14	30	43	**54**	52	42	27	6	−11	18	73
Port Arthur, Ont.	644	*7*	9	20	35	47	57	**63**	60	53	42	27	14	36	57
London, Ont.	860	22	*21*	30	44	45	65	**69**	67	61	49	37	26	46	48
Toronto, Ont.	379	23	*22*	30	42	53	63	**69**	67	60	48	37	27	45	47
Ottawa, Ont.	260	*12*	13	24	41	55	65	**70**	66	58	46	32	17	42	58
Montreal, Que.	187	*14*	15	26	42	56	65	**70**	67	59	47	33	20	43	56
Quebec, Que.	296	*10*	12	23	37	51	62	**67**	64	56	44	30	16	39	57

[1] lat. 76° 17′ N., long. 119° 28′ W.

Canada (continued)

	Alt. feet	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year	Range
Halifax, N.S.	83[1]	24	*23*	30	39	49	58	65	**65**	59	49	39	28	44	42
St. John's, Nfld.	125	24	*22*	27	35	43	52	60	**60**	55	47	37	29	41	39
Hebron, Lab.	60	*−6*	−5	6	18	32	40	47	**48**	41	31	20	4	23	54

United States of America

	Alt. feet	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year	Range
Albany, N.Y.	97	*23*	24	33	47	59	68	**73**	71	63	52	40	28	48	50
Albuquerque, New M.	5,200	*35*	40	47	55	64	73	**76**	74	68	56	44	35	56	41
Austin, Nev.	6,594	*28*	32	36	44	51	61	**70**	68	59	48	39	30	47	42
Boisé, Id.	2,770	*29*	35	43	50	48	66	**74**	73	62	52	41	32	51	45
Boston, Mass.	124	28	*28*	36	46	57	67	**72**	70	64	53	42	32	50	44
Charleston, S.C.	48	*50*	52	58	65	73	79	**82**	81	77	68	58	51	66	32
Chicago, Ill.	824	*24*	26	36	47	57	67	**73**	71	65	54	40	29	49	49
Cleveland, Ohio	571	*27*	27	35	46	58	67	**72**	70	64	53	41	31	49	45
Denver, Col.	5,272	*30*	33	39	47	57	67	**72**	71	63	51	40	32	50	42
Des Moines, Iowa	860	*20*	23	36	50	61	71	**75**	73	65	53	38	26	49	55
Duluth, Minn.	1,133	*9*	13	24	38	48	58	**65**	64	56	45	29	16	39	56
Eureka, Calif.	64	*47*	47	48	50	52	55	**56**	56	56	54	51	48	52	9
Galveston, Tex.	69	*54*	56	63	69	75	81	**83**	83	80	73	63	56	70	29
Harrisburg, Penn.	361	*30*	30	40	51	62	70	**75**	73	66	55	43	33	52	45
Helena, Mont.	4,110	*20*	24	33	44	52	60	**67**	66	56	45	33	25	44	47
Indianapolis, Ind.	822	*28*	31	41	52	63	72	**76**	74	67	55	42	32	53	48
Miami, Fla.	5	*68*	68	71	74	77	80	**82**	**82**	81	78	73	69	75	14
Montgomery, Ala.	240	*49*	51	58	65	73	80	**82**	81	77	66	56	49	66	33
Nashville, Tenn.	573	*39*	41	50	59	68	76	**79**	78	72	61	49	41	59	40

[1] 240 since 1933.

TEMPERATURE (°F.) (*continued*)

United States of America (continued)

	Alt. feet	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year	Range
New Orleans, Louis.	51	55	57	63	69	75	81	82	82	79	71	62	56	69	27
New York, N.Y.	314	31	31	39	49	60	69	74	72	67	56	44	34	52	43
Olympia, Wash.	coast	38	41	45	49	55	59	63	63	58	51	45	41	51	25
Omaha, Neb.	1,103	22	26	37	51	62	72	77	75	66	54	39	27	51	55
Oswego, N.Y.	335	24	24	31	43	53	63	69	68	61	50	39	28	46	45
Pike's Peak, Col.	14,111	2	4	8	13	23	33	40	39	32	22	11	6	19	38
Pine Bluff, Ark.	215	44	46	55	63	71	79	82	82	75	64	53	45	63	38
Pittsburgh, Penn.	842	31	32	40	51	62	70	74	72	67	55	43	34	53	43
Portland, Maine	99	22	23	32	43	53	62	68	66	60	50	38	28	45	46
Raleigh, N.C.	390	42	43	51	59	68	75	78	77	72	61	51	43	60	36
Sacramento, Calif.	71	46	51	54	59	63	70	73	73	70	63	54	46	60	27
Salem, Or.	120	39	43	46	51	56	62	67	67	61	54	46	41	53	26
Salt Lake City, Ut.	4,366	29	34	42	50	58	67	76	75	64	53	41	32	52	47
San Antonio, Tex.	701	53	56	63	69	75	81	83	84	79	71	61	54	69	31
San Diego, Calif.	93	55	55	57	59	61	64	67	69	67	63	60	56	61	14
San Francisco, Calif.	207	50	53	54	55	57	59	59	59	61	61	57	51	56	11
St. Louis, Missouri	568	32	35	45	56	66	75	79	77	70	58	45	35	56	47
St. Paul, Minn.	848	12	16	29	46	58	67	72	69	61	48	32	19	44	60
Vicksburg, Miss.	247	48	51	59	66	73	79	81	81	77	67	57	50	66	33
Washington, D.C.	75	34	35	43	53	64	73	77	75	68	57	45	36	55	43
Yuma, Ariz.	141	54	59	64	70	76	85	91	90	84	73	62	55	72	37
Alaska															
Barrow	13	−17	−17	−15	0	20	35	40	38	31	17	0	−12	10	57
Fort Yukon	417	−21	−16	0	22	43	58	61	55	42	21	−6	−20	20	82
Nome	17	3	6	9	20	34	46	50	50	42	29	16	8	26	47
Sitka	15	33	34	37	42	47	52	55	56	52	46	39	35	44	23

PRECIPITATION (inches)

Canada

	Alt. feet	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Coppermine, NWT.	13	0·6	*0·4*	0·6	0·8	0·5	0·8	1·3	**1·9**	1·0	1·2	0·8	0·6	10·7
Fort Good Hope, NWT.	214	0·5	0·5	*0·5*	0·5	0·7	1·0	1·5	**1·7**	1·2	1·1	0·8	0·6	10·6
Mould Bay, NWT.	50	$<$0·1	0·1	0·1	$<$0·1	0·2	0·4	**0·8**	0·3	0·5	0·1	0·1	$<$0·1	2·6
Dawson, Yukon	1,062	0·9	0·7	0·5	*0·5*	1·0	1·2	1·5	**1·5**	1·4	1·2	1·1	1·0	12·6
Atlin, B.C.	2,240	1·1	0·9	0·6	*0·3*	0·4	0·8	**1·2**	0·9	1·1	1·3	1·3	1·1	11·1
Prince Rupert, B.C.	170	9·8	7·6	8·4	6·7	5·3	*4·0*	4·8	5·1	7·7	12·2	**12·3**	11·3	95·2
Victoria, B.C.	228	4·5	3·0	2·3	1·2	1·0	0·9	*0·4*	0·6	1·5	2·8	4·3	**4·7**	27·1
Vancouver, B.C.	45	8·6	5·8	5·0	3·3	2·8	2·5	*1·2*	1·7	3·6	5·8	8·3	**8·8**	57·4
Kamloops, B.C.	1,133	1·0	0·7	*0·4*	0·4	0·9	**1·3**	1·0	1·1	0·8	0·7	0·9	1·1	10·2
Prince George, B.C.	1,870	1·8	1·2	1·4	*0·8*	1·3	2·1	1·6	1·9	**2·0**	2·0	1·9	1·9	20·0
Fort Vermilion, Alta.	950	0·6	*0·4*	0·6	0·6	1·1	1·8	**2·1**	1·7	1·3	0·7	0·6	0·5	12·1
Edmonton, Alta.	2,219	0·9	*0·6*	0·8	0·9	1·9	3·1	**3·3**	2·3	1·3	0·7	0·7	0·8	17·4
Banff, Alta.	4,521	1·3	*0·9*	1·2	1·1	2·0	**2·8**	2·0	2·2	1·7	1·2	1·4	1·4	19·2
Calgary, Alta.	3,540	*0·5*	0·5	0·8	1·0	2·3	**3·1**	2·5	2·3	1·5	0·7	0·7	0·6	16·7
Medicine Hat, Alta.	2,144	0·6	*0·6*	0·6	0·8	1·6	**2·4**	1·7	1·4	1·1	0·6	0·7	0·7	12·8
Winnipeg, Man.	760	0·9	*0·9*	1·2	1·4	2·3	**3·1**	3·1	2·5	2·3	1·5	1·1	0·9	21·2
Churchill, Man.	44	*0·5*	0·6	0·9	0·9	0·9	1·9	2·2	**2·7**	2·3	1·4	1·0	0·7	16·0
Port Arthur, Ont.	644	0·9	*0·8*	0·9	1·5	2·1	2·8	**3·6**	2·8	3·4	2·5	1·5	0·9	23·7
London, Ont.	860	**4·0**	3·5	2·8	2·9	*2·8*	3·1	3·2	2·8	3·0	2·9	3·7	3·5	38·2
Toronto, Ont.	379	2·7	*2·4*	2·6	2·5	2·9	2·7	**2·9**	2·7	2·9	2·4	2·8	2·6	32·2
Ottawa, Ont.	260	2·9	*2·2*	2·8	2·7	2·5	**3·5**	3·4	2·6	3·2	2·9	3·0	2·6	34·2
Montreal, Que.	187	3·8	3·0	3·5	*2·6*	3·1	3·4	**3·7**	3·5	3·7	3·4	3·5	3·6	40·8
Quebec, Que.	296	3·5	2·7	3·0	*2·3*	3·1	3·7	**4·0**	4·0	3·6	3·4	3·2	3·2	39·9
Halifax, N.S.	83[1]	5·4	4·3	4·9	4·5	4·1	4·0	*3·8*	4·4	4·1	**5·4**	5·3	5·4	55·7
St. John's, Nfld.	125	5·3	4·9	4·6	4·2	3·6	*3·5*	3·7	3·7	3·8	5·3	**5·9**	5·5	53·8
Hebron, Lab.	60	0·9	0·7	0·9	1·1	1·6	2·1	2·7	2·7	**3·3**	1·6	1·1	*0·6*	19·3

[1] 240 since 1933.

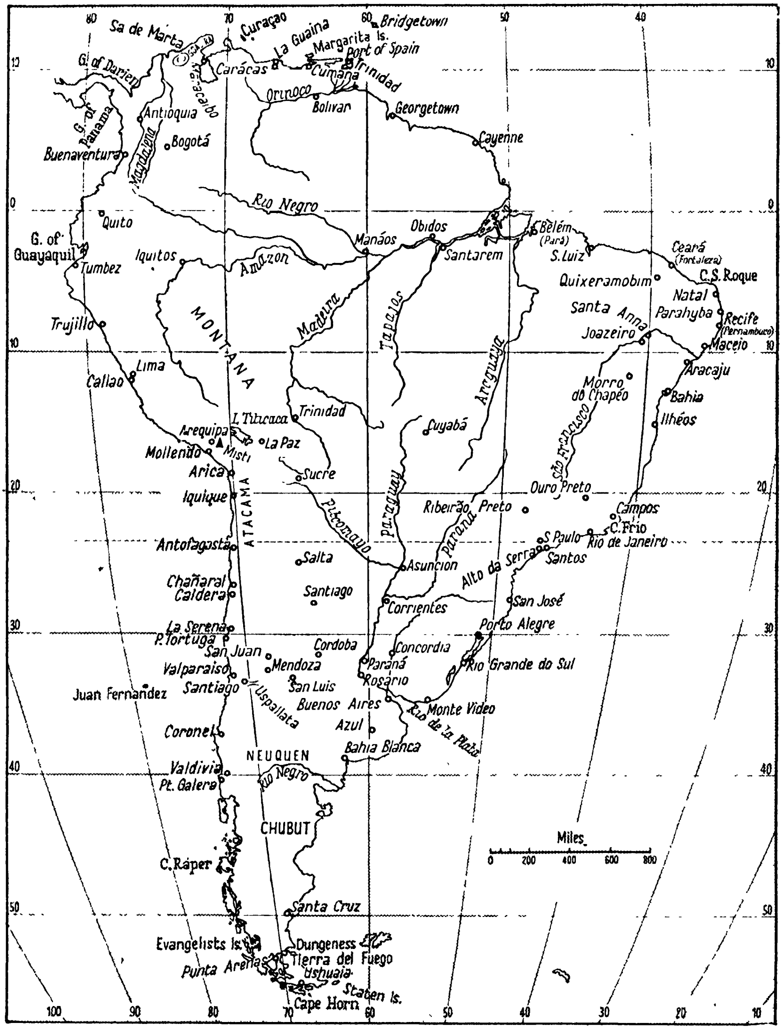
PRECIPITATION (inches) (*continued*)

United States of America

	Alt. feet	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*
Albany, N.Y. . .	97	2·2	*2·2*	2·7	2·7	2·7	**3·4**	3·3	3·3	3·2	2·5	2·5	2·3	33·1
Albuquerque, New M. .	5,200	0·3	*0·3*	0·4	0·7	0·7	0·7	**1·5**	1·3	0·9	0·7	0·5	0·5	8·4
Austin, Nev. . .	6,594	1·1	1·3	1·4	**1·7**	1·6	0·6	0·6	0·6	*0·6*	0·8	0·8	1·0	12·2
Boisé, Id. . . .	2,770	**1·5**	1·4	1·4	1·2	1·2	0·9	0·3	*0·2*	0·5	1·1	1·4	1·3	12·5
Boston, Mass. . .	124	3·4	3·1	3·6	**3·7**	2·9	3·2	3·3	3·3	3·5	*2·8*	2·9	3·4	38·9
Charleston, S.C. . .	48	2·4	3·0	2·7	2·3	3·0	3·8	**6·1**	5·6	4·3	2·8	*1·8*	2·3	40·3
Chicago, Ill. . . .	824	1·7	*1·6*	2·7	2·6	3·4	3·4	3·1	3·3	**3·5**	2·4	2·1	1·9	31·9
Cleveland, Ohio . .	571	2·6	*2·1*	2·7	2·6	2·6	2·8	**3·4**	2·7	3·1	2·6	2·4	2·3	31·9
Denver, Col. . . .	5,272	*0·3*	0·5	1·1	**2·1**	2·0	1·3	1·6	1·5	1·2	1·0	0·6	0·7	14·0
Des Moines, Iowa . .	860	*1·0*	1·1	1·8	2·6	4·2	**4·2**	3·2	3·7	4·0	2·2	1·6	1·1	30·7
Duluth, Minn. . .	1,133	1·0	*0·9*	1·5	1·9	2·9	**3·7**	3·6	3·0	3·3	2·2	1·5	1·0	26·5
Eureka, Calif. . .	64	**6·7**	6·1	5·1	2·9	1·4	0·7	*0·1*	0·2	0·9	2·3	5·4	5·7	37·6
Fort Yukon, Alaska .	417	0·4	0·4	*0·3*	0·3	0·5	0·8	1·1	**1·3**	0·7	0·6	0·3	0·3	6·9
Galveston, Tex. . .	69	3·5	2·8	*2·5*	3·5	3·5	3·5	4·1	3·8	5·3	**4·5**	3·3	4·1	44·4
Harrisburg, Penn. . .	361	3·0	2·7	3·1	3·0	2·9	3·7	3·5	**4·1**	3·4	3·0	*2·0*	2·9	37·2
Helena, Mont. . .	4,110	0·7	*0·5*	0·8	1·0	2·1	**2·1**	1·1	0·9	1·2	0·9	0·6	0·7	12·5
Indianapolis, Ind. . .	822	3·0	*2·0*	3·9	3·5	**3·6**	3·6	3·5	3·4	3·4	2·7	2·7	2·9	38·3
Miami, Fla. . . .	5	2·5	1·9	2·3	3·4	7·1	**7·4**	*5·3*	6·4	8·9	**9·0**	3·3	*1·7*	59·2
Montgomery, Ala. . .	240	4·9	5·5	**6·0**	4·8	3·7	3·7	4·9	3·8	3·3	*2·6*	3·3	4·9	51·4
Nashville, Tenn. . .	573	4·6	3·4	**5·0**	3·9	4·0	3·9	3·7	3·5	2·9	*2·7*	3·1	4·2	44·8
New Orleans, Louis. .	51	4·5	4·1	5·0	5·5	5·2	5·0	**6·8**	6·1	5·3	4·1	*3·1*	4·9	59·7
New York, N.Y. . .	314	3·3	3·4	3·6	3·4	3·1	3·6	4·2	**4·2**	3·7	3·5	*2·5*	3·3	41·6
Olympia, Wash. . .	coast	8·3	6·3	5·2	3·2	2·3	1·6	*0·6*	0·7	2·3	4·5	8·4	**9·0**	52·4
Omaha, Neb. . .	1,103	*0·7*	0·9	1·2	2·0	3·0	**3·9**	3·1	3·2	3·4	1·9	1·3	0·9	25·5
Oswego, N.Y. . .	335	2·7	*2·5*	2·7	2·6	2·9	3·0	2·8	2·6	2·9	**3·3**	3·0	3·0	34·1
Pike's Peak, Col. . .	14,111	1·6	1·5	2·0	3·5	3·8	1·6	**4·2**	3·8	1·7	*1·4*	1·9	2·6	29·6

United States of America (continued)

	Alt. feet	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Pine Bluff, Ark.	215	5·2	3·9	5·3	5·4	4·6	3·7	3·7	*3·2*	3·4	3·2	4·1	**5·6**	51·3
Pittsburgh, Penn.	842	3·0	2·2	3·2	3·1	2·9	**3·7**	3·5	3·3	2·5	2·5	*2·1*	2·7	34·8
Portland, Maine	99	**4·4**	4·0	4·3	3·7	3·1	3·2	3·0	2·9	3·2	*2·9*	3·1	4·0	42·1
Raleigh, N.C.	390	3·3	3·8	3·7	3·5	3·6	4·7	**5·4**	5·1	3·9	2·6	*2·3*	3·5	45·5
Sacramento, Calif.	71	**3·3**	3·1	2·4	1·0	0·5	0·2	*0*	0	0·3	0·8	1·5	2·7	15·9
Salem, Or.	120	5·6	4·7	3·9	2·4	1·8	1·2	*0·4*	0·4	1·7	2·9	5·7	**6·5**	37·2
Salt Lake City, Ut.	4,366	1·3	1·5	**2·0**	1·9	1·9	0·7	*0·6*	0·9	0·9	1·4	1·3	1·3	15·8
San Antonio, Tex.	701	*1·5*	1·5	1·8	3·3	**3·5**	2·6	2·3	1·6	2·9	2·3	1·8	1·8	26·8
San Diego, Calif.	93	2·0	**2·2**	1·6	0·7	0·3	0·1	< *0·1*	0·1	0·1	0·5	0·7	1·8	10·1
San Francisco, Calif.	207	**4·4**	4·0	3·0	1·1	0·6	0·2	< *0·1*	< 0·1	0·4	0·9	2·1	3·6	20·2
St. Louis, Missouri	568	2·3	*2·0*	3·5	3·7	**4·2**	3·6	2·9	3·4	3·6	2·9	2·4	2·1	36·7
St. Paul, Minn.	848	*0·9*	0·9	1·4	2·1	3·5	**4·1**	3·2	3·2	3·1	2·2	1·3	0·9	26·8
Vicksburg, Miss.	247	4·9	4·7	**5·6**	5·2	4·2	3·4	4·3	3·2	*2·3*	2·6	3·5	5·5	49·4
Washington, D.C.	75	3·3	3·1	3·7	3·3	3·5	4·1	**4·5**	4·2	3·5	2·9	*2·5*	3·1	41·7
Yuma, Ariz.	141	0·3	0·4	0·3	0·1	< 0·1	< *0·1*	0·2	**0·5**	0·5	0·3	0·2	0·5	3·6
Alaska														
Barrow	13	0·2	0·2	0·1	*0·1*	0·1	0·3	**0·9**	0·7	0·5	0·6	0·3	0·3	4·2
Fort Yukon	417	0·4	0·4	*0·3*	0·3	0·5	0·8	1·1	**1·2**	0·6	0·6	0·4	0·3	6·7
Nome	17	1·1	0·8	0·8	*0·7*	*0·6*	1·1	2·5	**3·2**	2·7	1·6	1·0	1·1	17·3
Sitka	15	7·8	6·7	6·1	5·5	4·2	*3·3*	4·3	7·2	10·4	**12·8**	10·2	9·1	87·4



154. Place-names mentioned in the text; for Argentina see Fig. 169, Central America, Mexico, the West Indies, Fig. 121.

PART VI

SOUTH AMERICA. CENTRAL AMERICA. MEXICO. THE WEST INDIES

CHAPTER XXXVIII

GENERAL FEATURES

South America alone of the three southern continents projects far into middle latitudes. Unlike the land-masses of the north hemisphere it tapers poleward, with a resulting absence of that continental variety of temperate climate, with great extremes of temperature, which is characteristic of the north. Nowhere is any very large range of temperature from summer to winter found; even in the arid west of the Argentine Republic, where it is largest, it is only about 30°. Farther south the diminishing breadth of the continent more than neutralizes the usual tendency to increase of range in the higher latitude. The continent is widest in the neighbourhood of the equator, and the equatorial climate prevails over vast areas. But the lofty ranges and plateaux of the Andes extend from Panama to Cape Horn, and their highest altitudes have an arctic climate even on the equator; while South America has the widest expanse of true equatorial climate of all the continents, it also may claim to have the greatest area in equatorial latitudes with a cold or even an arctic climate. The Andes not only make their own climate by their height, but are also a very effective meteorological barrier between the lands on either side. South America is of interest as having extraordinarily abrupt contrasts of relief and, in consequence, of climate.

Oceanic Conditions

The Antarctic Current meets the coast of south Chile and spreads north and south. The north-going branch, the Humboldt or Peru Current, is driven to the equator by the SE. trade. Its direction makes it a cool current, but close in-shore still cooler water wells up to take the place of the surface layers

which the trade drives to the north-west. The main features of the climate of the coast are to be attributed largely to this cool water—much fog and cloud, absence of rain, and remarkably low temperature. The other branch goes south off southern Chile with no great abnormality of temperature; the prevailing winds are on-shore, and hence there is no upwelling cold water along this coast. The west coast of Colombia between the equator and Panama, beyond the reach of the Humboldt Current, is washed by the warm waters of the Equatorial Counter-current.

The east coast of the continent, on the other hand, has warm water nearly everywhere. The South Equatorial Current of the Atlantic meets the north-east coast of Brazil, which, projecting like a wedge, divides the great stream into two branches, one of which goes past the Amazon mouth, the Guianas, and Venezuela, into the Caribbean Sea, while the other goes southward as the warm Brazil Current, which in summer washes the coast as far as the River Plate, but in winter leaves the land about Cape Frio to maintain a southward course. Beyond the River Plate the Falkland Current is dominant, a cool current from the Southern Ocean, a few degrees cooler than the Brazil Current on its east in the same latitudes; in summer the River Plate is its farthest advance, but in midwinter the cold water continues to Cape Frio between the Brazil Current and the coast.

A direct effect of the oceanic conditions appears in the temperatures of the west and east coasts (see table, p. 468). Between the Gulf of Guayaquil and Callao the west coast is cooler than the east all the year. The difference is greatest in winter, amounting to about 12° in July, but is only about 4° in January, for a warm current from the north (el Niño) replaces the cool Humboldt Current off north Peru from January to April. Between Callao and 25° S. the west coast is about 10° cooler than the east in every month of the year, but south of 25° S. the summer months alone are appreciably cooler, with a deficit of about 10°; in winter the west coast is even warmer than the east in some latitudes, the oceanic on-shore winds being warmer than the land winds on the east of the continent.

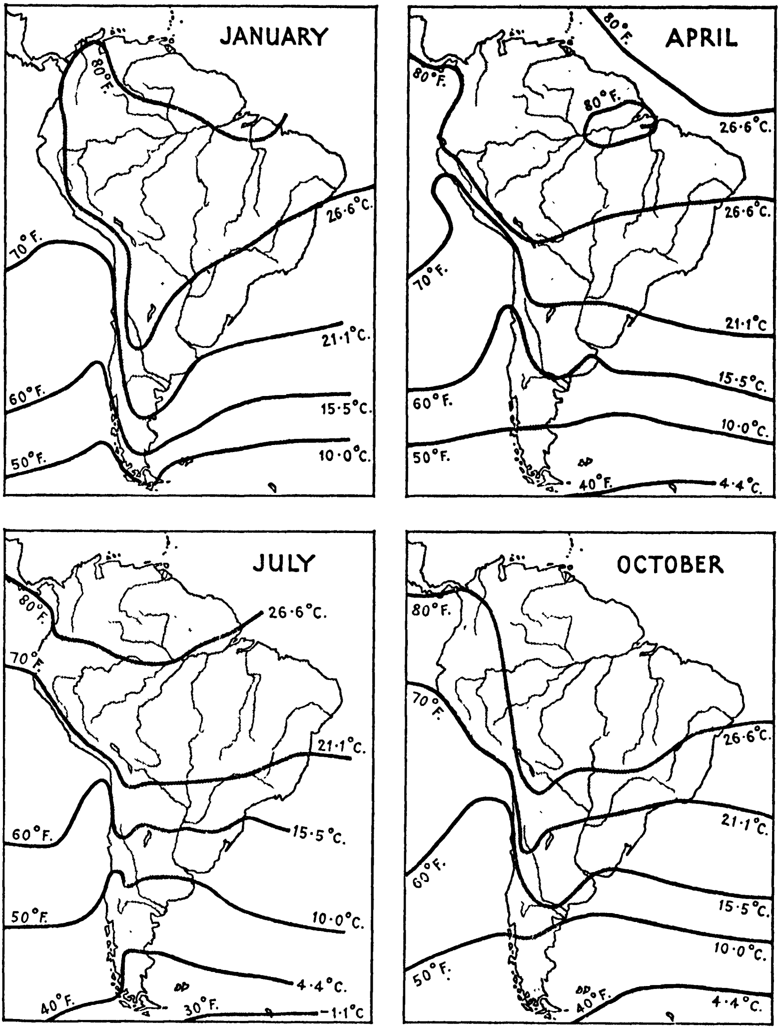


FIG. 155. Mean isotherms.

TEMPERATURE (Fig. 155)

Inter-tropical South America is considerably cooler, allowance being made for elevation, than the corresponding parts of Africa and Australia, owing to its greater cloudiness, heavier rainfall, and denser forests. In January the hottest area is the south of Brazil and the north of the Argentine Republic, in

July Venezuela and Guiana. Nearly the whole of the continent as far south as the tropic of Capricorn, except the west coast, has a mean monthly sea-level temperature of over 70° in every month. The south is much warmer in winter and cooler in summer than the same latitudes in North America and Asia. In the southern winter the 32° isotherm remains south of Cape Horn; but in China it swings equatorward as far as the 35th parallel in January. The narrowness of the land and the vastness of the surrounding oceans preclude any extreme winter cold in South America. And for the same reasons the summers are remarkably cool; the 50° isotherm for the warmest month crosses Tierra del Fuego in lat. 55° S.; in the northern continents it lies for most of its course inside the Arctic Circle. In the west of South America the isotherms have a very pronounced northward bend, especially in summer, owing to the cool Humboldt Current flowing north. The contrast between the west and east coasts of the continent is striking:

	Mean Temperature		
	Warmest month	*Coolest month*	*Annual range*
Lat. 8° S.			
Trujillo	77	63	14
Recife	82	76	6
Lat. 23° S.			
Antofagasta	70	57	13
Rio de Janeiro	79	69	9
Lat. 33° S.			
Valparaiso	64	53	11
Rio Grande	74	55	19
Lat. 40° S.			
Valdivia	62	47	15
Bahia Blanca	75	48	27

Pressure and Winds (Figs. 156 and 157)

The equatorial trough swings north and south with the sun in South America as in Africa. In April the lowest pressures are over the equator, and as the sun enters the north hemisphere the trough follows, till in July they cover the continent from the equator to Panama, an enormous area with a flat field of pressure, and probably extend north over Central America to join the low pressures over North America. By

November the trough returns to the equator, and in January reaches its farthest south in south Brazil. On the oceans it migrates less far, and on the Pacific coast remains north of the equator even in the southern summer, the cool seas to the south being unfavourable to low pressures. On the Atlantic it shifts only a few degrees from the equator.

In July the sub-tropical high pressures are centred about lat. 30° S. on the Pacific, 27° S. on the Atlantic, and a belt across the continent indicates the path of the travelling anticyclones which pass from the Pacific to the Atlantic. In January this latter is broken by the summer heat on the land, and detached anticyclones are left on the oceans, with pressures rather less than in July but steeper gradients. From the subtropics pressures decrease rapidly and fairly uniformly in the westerlies through the Roaring Forties to the Antarctic Circle; some details will be found on page 565.

Generalized streamlines, based, unfortunately, on inadequate data in the interior, especially north of the tropic, are shown in Fig. 157. In January the lowest pressures and the intertropical front have swung far south; the latter crosses the west coast in Colombia about 1° N., curves sharply over the Cordillera to the tropic in Paraguay, and thence north-east to the equator near the mouth of the Amazon. The area north of the front is filled by the NE. trade, which blows with moderate force from E. on the north coasts of the continent and up the Amazon, sluggishly from N. in the west of Brazil and from NW. and W. in the south. The east of Brazil, on the other side of the front, is under the SE. trade blowing from E. in north-east Brazil and from NE. south of lat. 5° S.; the limits of the SE. trade on the ocean near the coast are off the mouth of the Amazon and about lat. 15° S.

The west of the continent between 30° S. and the equator is dominated by the SE. trade of the Pacific, deflected on parts of the coast by the powerful sea-breeze to almost constant south-westerlies, and variable on land owing to the strong relief. The Gulf of Panama has northerlies.

South of the trades of the two oceans is the belt of subtropical variables, and beyond them the turbulent westerlies hold sway to Cape Horn and the Southern Ocean. To a large

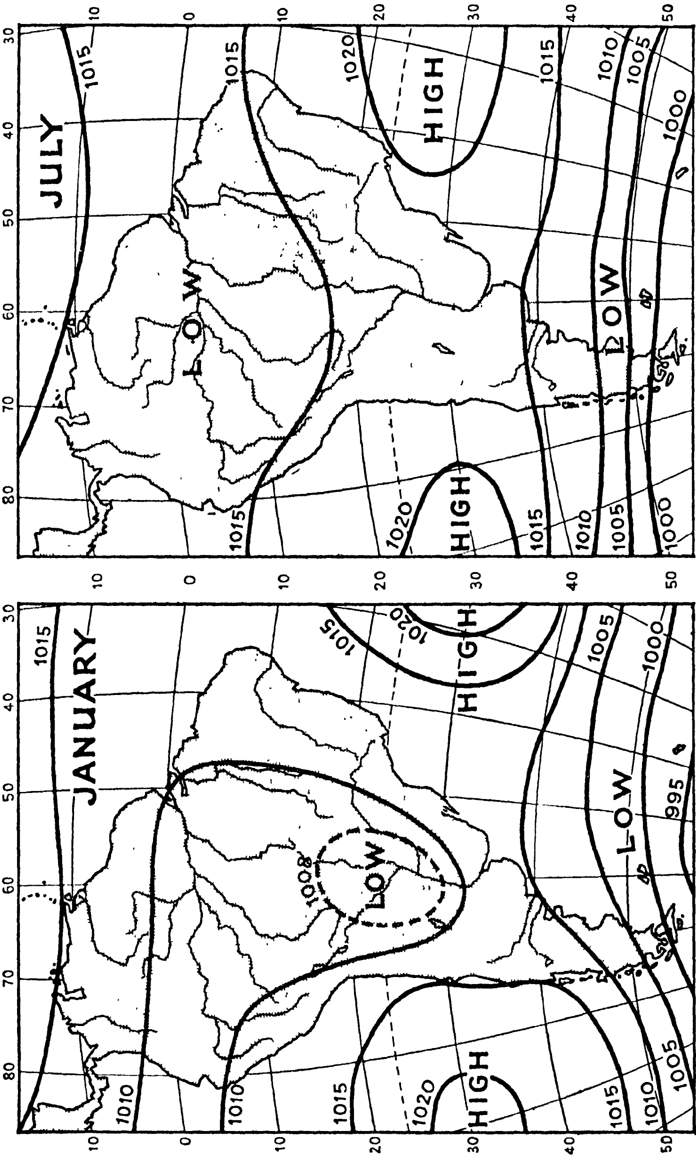


FIG. 156. Mean isobars.

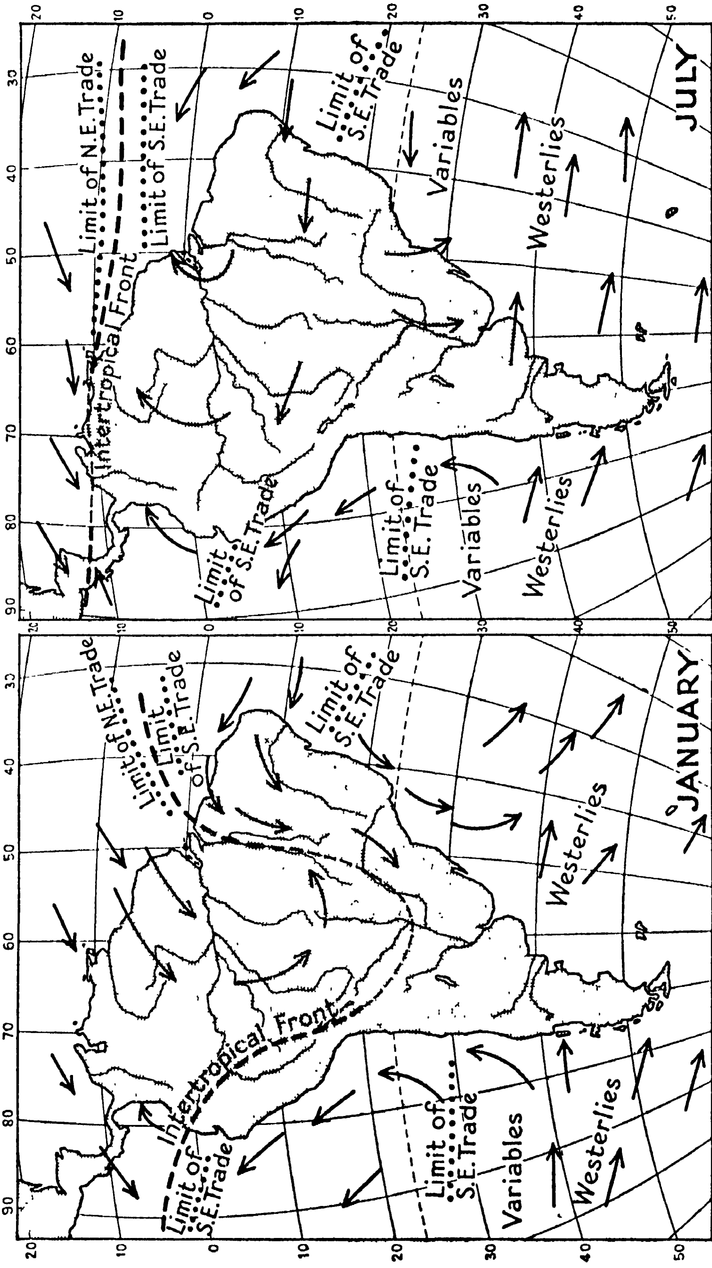


FIG. 157. Mean streamlines (intertropical front based on M. A. Garbell).

extent the westerlies seem to be able to cross the Andes, much lower here than farther north and dissected by many river valleys.

In July the equatorial trough reaches its most northerly position (Fig. 157), and the NE. trade does not normally extend beyond the north coast (and even there is interrupted by westerlies and calms in Colombia and the west of Venezuela). In the north-east the intertropical front migrates from its January position on the mouth of the Amazon only to the north of Venezuela. Tropical South America is filled by the SE. trade, the air-stream curving north in Amazonas and Pará and north-east beyond the Amazon. On the Atlantic the limits of the SE. trade are 5° N. and 15° S. near the coast. On the west of the continent the Gulf of Panama has northerlies, but southerlies also are frequent and strong; the coast of Colombia has light monsoonal south-westerlies and variables, and in the south of the Gulf of Guayaquil we enter the SE. trade which sweeps from far south beyond the tropic, blowing parallel to the coast. As in summer, variables are found in both oceans south of the trade, and beyond them, south of 35° S. in the Atlantic, 38° S. in the Pacific, are the westerlies. A significant point should be noted in Fig. 157; the intertropical front separates the tropical air-masses of the SE. trade of the South Atlantic and the NE. trade of the North Atlantic. The former seems to be inherently dry and gives little rain, except orographic, until it has crossed the equator into the north of the continent in the north-hemisphere summer. Similarly the NE. trade is normally not a rain-giver, but in the south-hemisphere summer it follows the intertropical front far into the middle of the continent as a light north-westerly, deflected, wind, and having become hot and damp (equatorial air) from its passage of the equatorial zone it provides the heavy rainfall of the vast interior of Brazil.

Wind-systems are subject everywhere to oscillations about their mean positions, and in addition local influences may be strong:

WIND DIRECTIONS, MEAN PERCENTAGE FREQUENCIES

		N.	*NE.*	*E.*	*SE.*	*S.*	*SW.*	*W.*	*NW.*	*Calm*
West Coast										
Lima,	Jan.	0	0	1	13	47	30	6	0	3
	July	1	*0*	1	14	42	20	9	3	10
Caldera,	Jan.	6	3	*1*	1	15	56	4	4	10
	July	16	7	5	4	25	21	*2*	9	11
Valparaiso,	Jan.	6	6	4	*2*	8	23	10	4	37
	July	9	9	9	8	7	12	14	*3*	29
Valdivia,	Jan.	10	*2*	3	10	19	7	17	9	23
	July	27	7	*2*	5	7	4	5	11	32
East Coast										
Georgetown,	Jan.	4	63	21	2	0	0	0	0	10
	July	4	46	21	9	2	0	0	0	18
Belém,	Jan.	15	22	8	4	5	*3*	8	4	31
	July	1	10	45	22	4	1	1	*0*	16
Bahia,	Jan.	15	18	32	14	3	3	*0*	4	11
	July	1	8	28	35	16	6	0	*0*	6
Buenos Aires	Jan.	23	24	16	8	7	*3*	4	15	0
(0800),	July	13	11	10	*8*	18	12	10	18	0
Bahia Blanca,	Jan.	10	*3*	7	4	8	6	17	45	0
	July	20	7	6	2	*2*	3	9	51	0
Staten Is.,	Jan.	10	7	4	*2*	11	24	21	20	1
	July	7	5	*4*	6	16	23	22	16	1
Interior										
Carácas,	Jan.	*0*	0	73	3	2	0	21	1	—
	July	0	0	88	10	2	0	0	*0*	—
Bolívar,	Jan.	0	45	47	8	0	0	*0*	0	—
	July	5	39	20	5	*2*	3	8	3	15
Manáos,	Jan.	23	15	35	5	17	*0*	5	0	—
	July	19	12	28	6	27	1	7	*0*	—
Asunción,	Jan.	14	14	14	12	19	6	*2*	3	16
	July	11	28	16	7	21	4	*1*	2	10
Paraná,	Jan.	19	15	18	16	15	5	7	*4*	1
	July	18	16	19	17	17	5	*2*	2	4

Two noteworthy features of South America are that its width in middle latitudes is not enough to develop a true monsoon in either winter or summer, and that in low latitudes its lowlands open widely and give entry to the easterlies in all seasons, so that the precipitation is much heavier over vast areas in South America than in Africa.

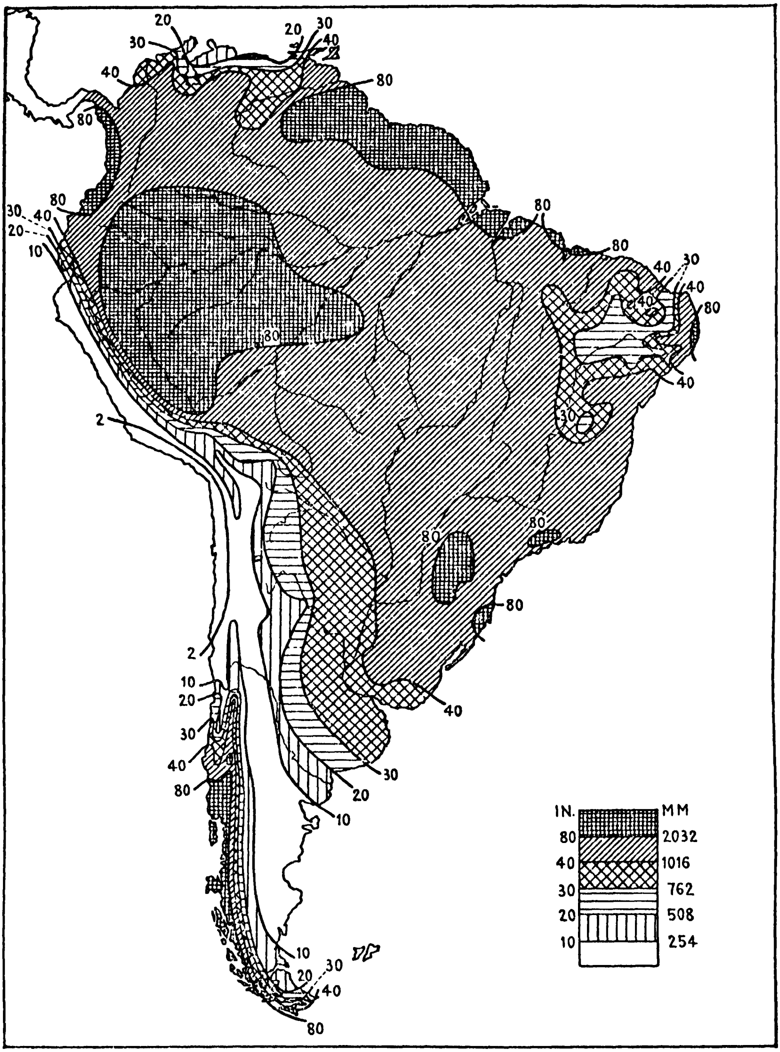


FIG. 158. Mean annual precipitation
(based on Knoch and, over Chile, Jefferson).

RAINFALL (Figs 158 and 159).

The heaviest rains of the continent are in three main regions, with smaller areas of orographic rain. The largest, with very large totals over enormous tracts, covers most of tropical South America east of the Andes; the rainy season is summer, and

the rain is associated with the intertropical front, near which it is of the usual tropical types with heavy convectional downpours and frequent thunder. The vapour is brought in by the N.E. trade of the North Atlantic deflected into a N. and

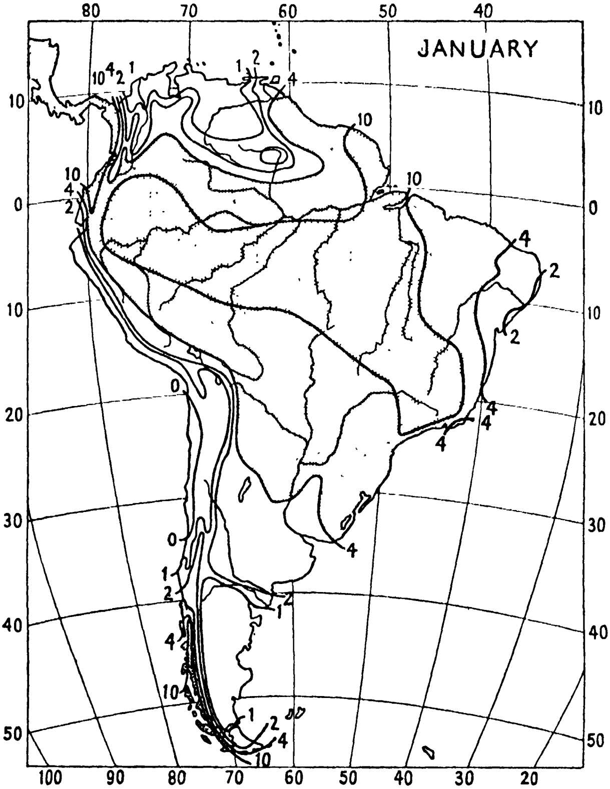


FIG. 159*a*. Mean precipitation (inches), January (based on Knoch).

NW. wind; it is here equatorial air, hot and moist from its passage over the equatorial zone, and finds ready entry up the Orinoco and Amazon lowlands. The tracts in the interior covered by it have their well-marked rainy season in the period October to March.

Most of the east littoral between the Amazon and lat. 30° S. is another area of heavy rainfall, different, however, both in type and season. Much of it has the greater part in the winter half-year, associated with surges of cold polar air from high

southern latitudes, which interacts frontally with the SE. trade of the South Atlantic (p. 500); the SE. trade in itself seems to provide little rain in any season except on high ground.

The third region outstanding for rain is south of 35° S. and

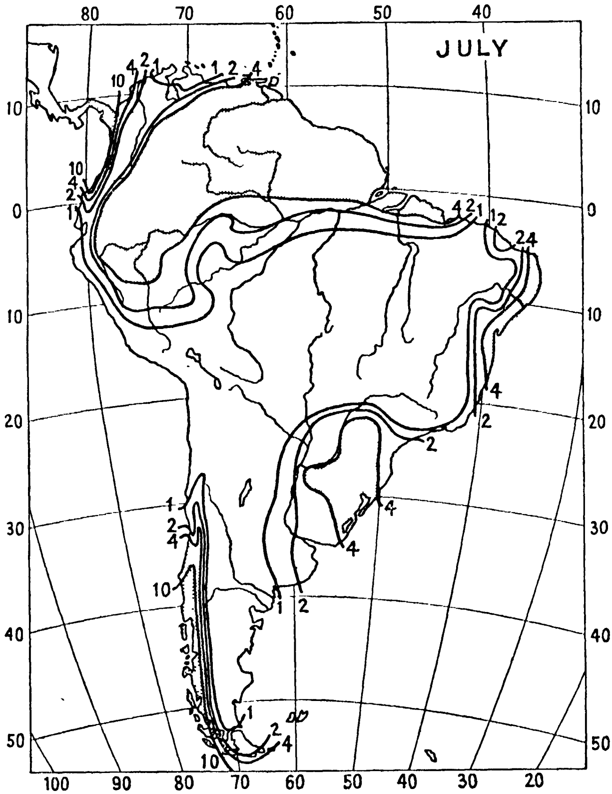


FIG. 159*b*. Mean precipitation (inches), July (based on Knoch).

is dominated by the westerlies; it is restricted to the mountains and the littoral; the rain is very heavy throughout the year, heaviest in winter, least heavy in spring.

As prominent as these areas of very heavy precipitation is the long arid belt which crosses the continent obliquely from the north-west to Patagonia. In the north and south the aridity is the orographic complement of the heavy rains on the windward sides of the cordillera; the central tract shows the usual effect of subsiding air in the sub-tropics.

CHAPTER XXXIX

THE WEST COAST, SOUTH OF THE EQUATOR

THIS region comprises the long strip between the shore and the upper slopes of the western Cordillera of the Andes. The Andes are narrowest, least lofty, and simplest in topography in the south; the width increases to about 300 miles and summits rise to over 15,000 feet near the tropic; north of the tropic the system is much wider and more lofty, and has distinct cor-

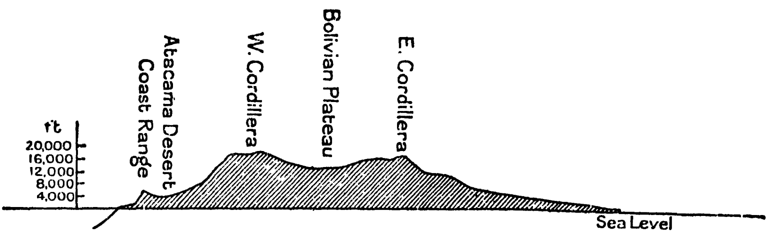


FIG. 160. Profile, lat. 20° S.

dilleras on east and west, enclosing extensive plateaux described in Chapter XL. Except in the north of Peru, a coastal range rises steeply from the ocean, but it is nowhere much higher than 5,000 feet so that it is insignificant in comparison with the giant ranges behind (Fig. 160), though high enough to shut out the maritime climate from the longitudinal valley between it and the Andes. It is not continuous, but long reaches separate the Atacama desert from the sea, and a lofty, but much dissected, range forms the west wall of the Central Valley of Chile (lat. 33°–42° S.). To the south the range forms the line of islands off the mainland to Cape Horn. This bold topography determines climatic as well as topographical regions, which extend most of the way from lat. 5° to 42° S.: (i) the coast; (ii) the higher slopes of the coastal range, where it exists; (iii) the interior longitudinal valley; (iv) the west slopes of the Andes up to about 6,000 feet; (v) the higher Andes.

From the Gulf of Guayaquil almost to Valparaiso stretches an arid land, dominated by the Pacific trade-wind all the year; the Andes entirely shut out the surface winds of the Atlantic and

the interior of the continent. The land being warmer than the sea the SE. trade is drawn in, so that the prevailing winds on the coast itself are south, parallel to the mountain-ranges. The coastal range sometimes gets a very little rain when the wind is more than usually moist, but in the valley on the east the chance of rain is always small. The only streams are those fed from the snows and rains of the lofty Cordillera, and these form strips of verdure with crops of sugar and cotton crossing the arid sand at distant intervals.

The all-important upwelling of cool water off this long coast, which dominates the climate, is described on page 465.

Peru

Rain is rare and scanty, but fog often covers the offing in winter, and on-shore winds carry vapour, and frequently fog, over the land. More often the fog is raised by turbulence and forms low stratus cloud (base at sea about 1,000 feet) which covers the hill slopes above 400 feet as with a dense chilly fog from which in some parts of the littoral a fine drizzle ('garua', which is described below) falls; at Lima this is persistent in winter, notably in the months June to September, but despite the continuous damp the mean annual precipitation is only 1·8 inches. While Lima and its zone are shrouded in this cloud the coasts are below it and have less unpleasant weather with only occasional drizzle, and the slopes above 2,500 feet usually look down on the upper surface of the sea of cloud and enjoy almost cloudless skies and bright sun. Summer is a great contrast, with dry and sunny weather in all these levels, but liable to heavy instability showers, which are frequent on the Andes above 5,000 feet. Fig. 161 shows the temperatures on the coast and the higher interior.

The north frontier of Peru forms a true physical not less than a political division, for it marks the sudden change from excessive to scanty rainfall; the north of the Gulf of Guayaquil has 40 inches of rain in the year, but Tumbez on the south coast only about 10 inches, and the land to the south for nearly 2,000 miles less than 5 inches. At Lima the mean is 2 inches, nearly all in the months June to September; heavy showers are rare on these lower slopes of the Andes, the usual rain being a fine drizzle or very wet mist called garua, which

suffices to call into life a bright show of vegetation after the arid months. The air is very damp, though the rainfall is that of a desert; a gloomy pall of stratus cloud may lie for weeks over the arid grey littoral, and rests on the surface a short distance inland forming the garuas. Darwin describes them:

> A dull heavy bank of clouds constantly hung over the land, so that during the first sixteen days I had only one view of the Cordillera behind Lima. It is almost become a proverb that rain never falls in the lower part of Peru. Yet this can hardly be considered correct; for during almost every day of our visit there was a thick drizzling mist, which was sufficient to make the streets muddy and

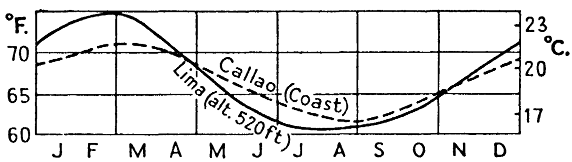


FIG. 161. Mean temperature.

> one's clothes damp; this the people are pleased to call Peruvian dew.

Winter is the cloudiest and dampest season on this coast—an interesting anomaly for a tropical region.

The cool arid conditions are liable to interruption at uncertain intervals by periods of tropical weather with heavy rain, when the normal cool Humboldt Current is replaced alongshore by an extension of the warm current, el Niño, from the north, a change which has remarkable effects on the bird- and fish-life of the region; in March 1925 Trujillo had about 16 inches of rain, a striking contrast to its mean annual total of about 1 inch (Murphy, R. C., in *Geogr. Rev.* 1926).

On the higher west slope of the Andes, above 7,000 feet near Arequipa, the rainfall increases, but here summer is the rainy season and the rain falls in heavy showers; Arequipa has an annual mean of about 4 inches. The mountain streams fed by this rain provide irrigation at the foot of the mountains for cotton-growing. The summer rain-belt descends lower towards the equator, and finally merges with the coastal equatorial rains about Guayaquil. Altitudes above 12,000 feet get some snow. Thus Peru and northern Chile have three rainfall regions

parallel to the coast—a very arid central strip, bounded by a region on the coast with drizzle-rain, most in winter, and on the other side by the upper slopes of the Cordillera with summer rain (or snow).

Temperature is remarkably low and uniform. At Callao, 12° S., the annual mean is 67°, at Mollendo, 450 miles south-east, 65°; the highest temperatures rarely reach 80° and never exceed 95°. Towards the interior temperature falls only slightly, in spite of the increasing altitude, as far as the beginning of the steep slope of the Cordillera. The annual range is only 8° at Callao, 12° at Lima. February is the warmest month in most places, but March at Callao.

Chile

The aridity of Peru is intensified south of the bend in the coast at Arica, and Chile may be truly described as rainless even on the coast, for the few uncertain showers are valueless for vegetation. The prevailing wind is SW.; other directions are rare at Iquique, where 42 per cent. of the observations (0800, 1400, and 2100) are calms, 47 SW., and only 11 from all other points. But on most of the coast the SW. winds of the daytime alternate with light and cool NE. or E. land-breezes at night. A heavy swell beats on the coast under the trade-wind, but gales are rare north of 30° S. The cool Humboldt Current is equally prominent as off Peru. The damp sea air at Iquique, where the mean monthly relative humidity ranges from 74 to 77 per cent., is very destructive to furniture and rusts all bare iron, but the mist-drizzle of Peru is not a feature of the climate. During 5 years no rain at all fell in the first 4, and a heavy shower gave 0·6 inch in July of the fifth year; thus the mean annual rainfall of the period was 0·1 inch, and winter is the 'rainy season'. On another occasion a single shower gave 2·5 inches. The climate may be described as rainless, but liable to a heavy shower at long intervals; on the average there is only one rain-day a year, and it has been remarked that a week of rain is much rarer than an earthquake. Other stations with annual means below 1 inch are Mollendo, Antofagasta, and Caldera. Southward the rainfall increases rapidly; Chañaral Island has 3·4 inches, Coquimbo 4·5 inches, Port Tortuga 6·7 inches, and on one occasion 5·5 inches fell here in 16 hours.

The fogs to which the coast is subject occur especially with winds from north and west. The sky is cloudy (with stratiform cloud) for the latitude in winter, cloudier in August at Iquique than in the British Isles. The cloud-layer meets the mountains about 2,000 feet above the sea, and supports a belt of vegetation which is almost entirely dependent on it for moisture. The coast has most fog (usually only a few hundred feet deep), cloud, and precipitation, the interior being sheltered by the coast range, which from the sea may often be seen enshrouded in cloud, while the gaps in the hills give a glimpse of the landscape beyond bathed in bright sunshine. The cloud usually clears after midday in summer, but in winter it may persist for days. The sea-breeze (virazon) and land-breeze (terral) are regular and prominent; the sea-breeze is often so strong on summer afternoons at Valparaiso and other places that boat-work is stopped. In summer the north Chile coast is sunny, the mean cloud being only 3 tenths in February. As in Peru the temperature is remarkably low, and the range small; on an average day in summer the thermometer does not rise above 75° even at Arica, or fall below 55° in winter; the absolute maximum at Arica and at Iquique is only 90°, but higher readings are known farther south, well over 90° at Valparaiso and Valdivia. Occasional readings of about 100° and remarkably low humidities have been experienced at a few stations, a result probably of föhn winds. The uniform temperature of Peru is continued in Chile; at Callao the annual mean is 67°, at Arica 65°, at Iquique 65°, and at Antofagasta 63°; even Valparaiso has 59°.

At this point we may conveniently summarize the fog conditions on the west coast. In the north, between the Gulf of Panama and the Gulf of Guayaquil fog is rare. It increases rapidly southward, and off Peru it may occur in any season, especially in the early morning, but is most frequent in the months June to November when it is often dense round lat. 8° S. The north of Chile has much low cloud but little fog (mean frequency only 1 day a year at Arica and Antofagasta). Fog becomes prominent again off central Chile, the mean frequency increasing from 29 days a year at La Serena (30° S.), to 50 days at Valparaiso, 55 days at Coronel (37·2° S.), and 92 days, a very high record, at Cape Raper (47·6° S.);

these means at coastal stations are considerably exceeded on the adjacent sea. On the land and the inner channels most of the fog is land-fog in winter, but the outer coasts have sea-fog, mostly in summer, formed in tropical air which originates in the Pacific anticyclone to the north-west and cools below its dew-point in crossing the cold water off the coast (usually in the warm sector of a Pacific depression).

The surface air over the cold current has the important abnormality of being warmer, on the average 4° warmer near the coast in lat. 5° S., than the water on which it rests; south of 20° S. the water is warmer, 4° warmer in 45° S., than the air.

Behind the coast range aridity is at a maximum. In the nitrate fields of the Atacama desert, shut off from the sea-mists, the air is very dry, and even the slightest shower is rare. Fortunately a few streams bring water from the Andes, and occasionally a flood descends on the desert when excessive rain falls on the mountains; but normally this is an unbroken desert of brown earth, and the air is hazy with dust and heat. Not a plant, even of the humblest form, is to be seen. It is warmer than the coast in spite of an altitude of 2,000 to 3,000 feet, and in summer the temperature may rise to 85° or 90°; but on winter nights radiation cools the ground rapidly and a thick fog often covers the desert with a temperature below freezing-point.

The upper western slope of the Cordillera overlooking the longitudinal valley has the characteristics of the corresponding region in Peru, with considerable rainfall in summer—evidently an extension of the summer rains of the Puna.

South of 30° S. the climate changes abruptly, the land is no longer arid, and beyond 40° S. is the zone of the westerlies, one of the rainiest regions on the earth. The westerlies come farther north in winter, and central Chile between 30° and 37° S. has a 'Mediterranean' climate, with rain in winter but dry sunny weather in summer. The winter rain and occasional snow is associated with depressions, in which 'northers' sometimes blow up suddenly with terrific force and raise a very heavy swell, but the mean barometric pressure is higher in winter than in summer. The comparatively foggy, cloudy, rainy, and equable, coastal strip is to be distinguished from the warm and

drier Central Valley. At Valparaiso on the coast the mean monthly temperature ranges from 64° in January to 53° in July, and the thermometer rarely rises above 85° or falls below 38° (absolute extremes 94° and 36°). The corresponding climatic region of Europe is represented by Lisbon, which, however, though 400 miles nearer the pole, has considerably warmer summers, but cooler winters. Valparaiso gets 20 inches of rain a year, 84 per cent. of it in the 4 months May to August;

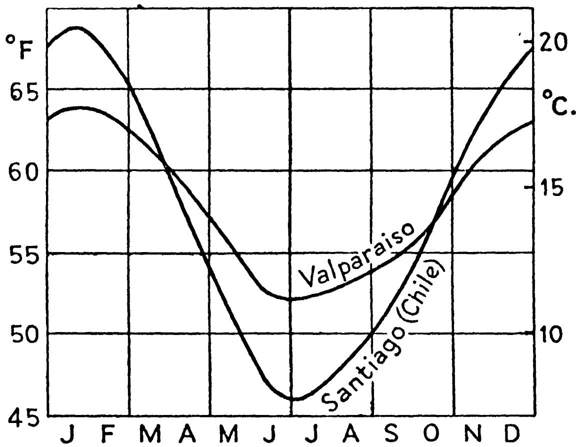


FIG. 162. Mean temperature.

as in other 'Mediterranean' regions, heavy downpours may give large totals, 7·3 inches having been recorded in a day. This is one of the least cloudy parts of the west coast between the equator and Cape Horn, but an unbroken layer of stratus often covers the coast in winter, and spreads some distance into the Central Valley, the mean cloud cover being about 7 tenths in the morning; summer is much brighter. Fog is rather frequent (50 days a year at Valparaiso). In the Central Valley, sheltered by the coast range, summer is warmer, but winter considerably cooler, than on the coast (Fig. 162); Santiago, 1,706 feet above the sea, has recorded extremes of 95° and 24°, and frost occurs throughout the winter half-year, being very frequent in July, more frequent than on the lower Andes which are at a greater altitude; on the other hand, readings above 100° are recorded in parts of the Central Valley subject to föhn winds. Santiago has far cooler summers than the eastern basin

of the Mediterranean region of Europe. The annual rainfall is 14 inches, and with the available irrigation suffices for such fruits as peaches, grapes, and oranges. Snow is not unknown but is rare in the north. The climate of central Chile is delightful for Europeans in most respects; but thick fog often forms in tropical maritime air over the Valley on clear nights, and the snows may come far down the slopes of the Andes in winter, blocking the passes for weeks.

Beyond 37° S. the westerlies are dominant all the year, so that rain falls in summer as well as in winter though in less amount; Valdivia has over 2 inches in every month. This is a forested land. The heavy rainfall is, in part, a result of the sea-surface temperature; instead of the cool upwelling water which is so prominent in the north the Pacific Drift brings water rather warmer than normal which provides copious vapour. Valdivia gets 103 inches of rain a year and some tracts of the Andes more than 200 inches. The totals are large, but rather lower, in the south, exceeding 80 inches all the way to Cape Horn, and summer is the rainiest season. Evangelists Island has 101 inches; it is one of the most cloudy spots on the globe, with mean cloud-amount 9 tenths.

The mean wind directions at some representative stations are given on page 473. The winds in the south are notoriously stormy; at Evangelists Island the mean speed is 35 miles an hour—about 3 times the speed in the south of England—and 151 miles an hour from north-west has been recorded; the winds change little from winter to summer, and a very heavy swell rolls in from the ocean. The Strait of Magellan shares the wild weather, the violent squalls being known there as Williwaws. The increasing storminess towards the south is shown by the number of days with gales at sea near the coast (*South American Pilot*, III):

Lat. °S.	*Summer*	*Autumn*	*Winter*	*Spring*
25–30 . .	0	1	2	2
35–40 . .	2	7	8	3
45–50 . .	10	14	14	13

Winter is mild in this stormy region but summer remarkably cool, the February mean at Evangelists Island being only 47°. The range of temperature is small, for the absolute extremes

are 59° and 24°; the former figure is significant of the cool summers. Owing partly to the cool summers, partly to the excessive precipitation, the snow-line on the southern Andes is as low as 2,600 feet (3,000–4,000 feet round the Strait of Magellan), and glaciers reach the sea at the heads of the fiords south of 46° S.

After crossing the Andes the westerlies blow over Patagonia as dry winds, and at the eastern base of the mountains föhn effects are often developed; but the scanty precipitation of Patagonia is partly due to the cool Falkland Current since winds from the east in front of depressions are cool and can give little rain. An interesting result is that the heavy rain of the west slopes of the Andes has made the rivers on that side work east and capture the headwaters of the feebler east-flowing streams. The rapid decrease is seen from the following series:

MEAN ANNUAL RAINFALL

Evangelists Island (off west end of Strait of Magellan)	101 inches
Punta Arenas (Strait of Magellan) . . .	15 ,,
Dungeness (east end of Strait of Magellan) . .	10 ,,

In most of Patagonia autumn, not winter, is the rainiest season.

CHAPTER XL

THE ANDES PLATEAU

THE plateau extends from the equator to the tropic of Capricorn, through Ecuador, Peru, and Bolivia, at an elevation averaging 9,000 feet in Ecuador and over 12,000 feet in Bolivia. The ranges of the Andes rise in fairly continuous walls on both sides, with peaks more than 20,000 feet high. The region is above the lower atmosphere of the west coast and the Amazon lowlands, and belongs to the middle troposphere.

ECUADOR

Quito (9,350 ft.) is representative of the lower Puna, a bleak region with some cultivation but no forests and hardly any trees. Potatoes and barley are the chief crops, and even these are not successful a few hundred feet above the town. Perpetual

snow lies above 15,000 feet, the snow-line being rather lower on the eastern Cordillera with its heavier precipitation than on the western, and the highest mountains, notably Chimborazo, bear glaciers. Quito with a mean annual temperature 20° lower than the west coast is not so cold as might have been expected from its altitude, a result rather of the abnormal cold of the Ecuador coast than of any remarkable warmth at Quito.

Perhaps the most striking feature of the temperature and weather is the remarkable uniformity from day to day and

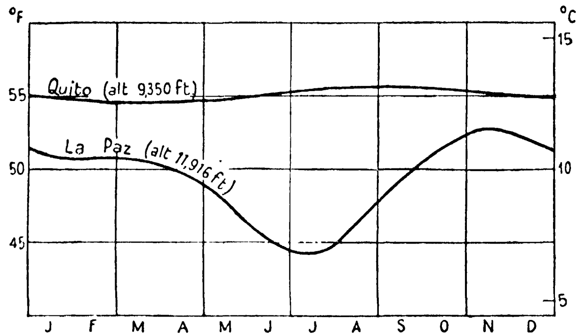


FIG. 163. Mean temperature.

from season to season, a reminder that Quito is on the equator in spite of the absence of equatorial heat (Fig. 163). The mean temperature throughout the year is much the same as in the south of England in May, and Quito has been said to enjoy a perpetual spring. The annual range is less than 1°, and the extremes are moderate, for the thermometer is rarely above 75° by day or below 35° at night. The rarefied air favours radiation, and ground-frost is frequent in the inversion-calms which often cover the plateau round the town (but katabatic winds from the Cordillera are sometimes strong and cold).

Though Quito is on the equator the rainfall régime is rather that of the south hemisphere, with comparatively little rain in June, July, and August, the months September to May forming the rainy season. The annual total, 44 inches, is only about half as much as in the Amazon lowlands, owing partly to the low temperature, and still more to the prominent rain-shadow effect in the great valleys of the Andes. The east and to a less degree the west Cordillera condense the vapour of the

prevailing east winds and are usually hidden in cloud with heavy precipitation.

It is generally agreed that if Quito has a perpetual spring it has the unpleasant, rather than the pleasant, features of that season, with sudden changes from hot sun to chilly wind and snow. The complex sequence of daily weather is in great contrast to the uniformity of the climate from month to month. The night and early morning are cold and raw, but the powerful sunshine raises the temperature rapidly, and by noon it feels hot in the sun, though in the shade it is still cool. About midday clouds gather, and may develop into a violent thunderstorm in the afternoon with heavy rain, hail, and frequently snow. These clouds and storms are mainly convectional, and they die away after the heat of the day which caused them. During the rains only 2 afternoons a month are clear, and in the whole year it is clear at noon on only 45 days, but at sunrise clear skies are more than three times as frequent. The early mornings are fine, and the air at these great altitudes is remarkably clear; but in the afternoons the clouds hang low over the gloomy landscape, so that the mountains are almost invariably hidden, and hail, snow, and rain chill the air.

Bolivia

Bolivia, being at some distance from the equator, has well-marked seasons. The clearer skies give temperatures somewhat higher than in Ecuador if allowance is made for the greater altitude. At La Paz, lat. 16·5° S., the mean of the warmest month, November, is 53°, of the coolest, July, 44° (Fig. 163). The weather is warmest just before the heaviest rains set in. The rainy season is summer, the overhead sun favouring convectional rainfall in the inter-tropical front; May, June, and July are almost rainless. La Paz has 23 inches, but the total is probably less than 10 inches in the middle of the plateau, which is overshadowed by the ranges of the Andes and is crossed by the arid belt which extends obliquely from Patagonia to the west coast. The daily cycle during the rains is the same as is described above for Quito. The morning is clear, but as the heat increases masses of cloud are seen rising on the eastern Cordillera, and pouring through the gaps from the

moist montaña beyond the mountains, till they overspread the sky and usually give a violent thunderstorm. The loudness of the crashing thunder impresses visitors; the electrical phenomena may be specially vigorous, or perhaps the peals are merely intensified by echoes from the mountain walls. During the rains the rivers swell, and Lake Titicaca rises to 5 feet above its winter level. But the air is very dry in the dry season; the plateau is a region of continental drainage. Sir Martin Conway observed during his mountaineering expeditions that remarkably little water was derived from the melting of the ice of the glaciers, and very few avalanches fell, facts which he attributed to the rapid evaporation of the snow and ice. The snow-line is very high, few of the summits in Bolivia reaching it. Above 13,000 feet are the bare uncultivable paramos up to about 18,000 feet, where perpetual snow begins. As in Ecuador the snow-line is lower towards the damp Amazon basin than on the west.

The diurnal range of temperature is everywhere large on this high plateau, especially at places which, like La Paz, are in hollows. In the clear dry air cooling is rapid, and frost is recorded at La Paz in every month of the year; probably during the dry season every clear night has ground-frost, and the shores of Lake Titicaca are frozen. But the sun's rays are powerful, and in the dry season the air is about 25° warmer at midday than before sunrise; the contrast between sunshine and shade is very noticeable; Conway gives a vivid picture of it:

> Early in the morning and late in the evening, when the sun is below the horizon, the cold is liable to be intense even in September and one suffers from almost frozen feet. In the winter, when the winds blow and the frosts are yet more severe, the dry cold is so trying that even the natives cover up their faces in thick woollen masks, and wrap shawls about their heads and ponchos over their bodies. But as soon as the sun is a little way above the horizon, its direct rays scorch the traveller with their great heat, so that he soon begins to pray for the night, as the lesser evil of the two. . . . By day the burning sunshine so envelops all the brown, dry, dusty ground that everything in view seems to vanish in brightness; and the eye, unprotected by dark glass, cannot gaze steadily in any direction. . . . When the sun is hottest little cyclones raise dust whirlwinds which dance along, often by scores at a time.

PERU

Transitional between Ecuador and Bolivia, the north is almost equatorial and differs little in climate from similar levels of Ecuador (but most of it is much lower than Ecuador, being deeply dissected by the headwaters of the Amazon). The south is similar to the same altitudes of the plateau of Bolivia (but Peru is much higher than Bolivia).

Barometric pressure on the Puna is only about 675 mb. (20 inches), and visitors suffer much from mountain-sickness. Even natives who have to travel from the coast to the Puna are not immune. The 'soroche', as the complaint is called locally, causes breathlessness and palpitation, loss of appetite, and sometimes nose-bleeding. Lung troubles are common at these high altitudes.

On the ranges and the plateau the wind blows very strong, and often sweeps through the passes with such excessive violence, especially by day, that traffic is held up. The temperature may be below freezing-point and the sky quite clear all the time. The cold polar winds are known as Surazos.

CHAPTER XLI

SOUTH AMERICA NORTH OF THE EQUATOR

COLOMBIA, Venezuela, the Guianas, and a small part of Brazil make up this region. The NE. trade blows on the coasts (except the Pacific coast of Colombia) all the year, strongest and steadiest in winter when the equatorial low pressures are over the south of Brazil, but interrupted by calms and variables, especially inland, in summer which is the rainy season. The area is large and has many climatic variations, distinguished chiefly by the rainfall, as is usual in the tropics: (1) the littoral, (2) the llanos of Venezuela, (3) the ranges of the Andes (long stretches in Colombia exceeding 15,000 feet) and the plateaux of Venezuela and the Guianas. The first of these must be subdivided into (*a*) the coasts of Colombia on the Pacific and on the Caribbean Sea as far as Cartagena, with more than 40 inches of rain a year and a great deal more, over 200 inches, on the Pacific, where Buenaventura has 280 inches evenly distributed over the year; (*b*) the remarkably dry coast from the

Goajira Peninsula to Cumana, Venezuela, with less than 20 inches; (*c*) the rest of the coast of Venezuela and the Guianas, with more than 80 inches.

RAINFALL

1(*a*). The Pacific coast has probably the largest rainfall of the continent, extremely heavy in all seasons, with maxima in April and September. This is a result of the intertropical front remaining over the coast in winter, and swinging only a short distance north in summer, so that light SW. winds, saturated with vapour from their passage over the hot Equatorial Counter-current, blow on-shore all the year and meet the steep slopes of the Coastal range and the lofty western ranges of the Andes. The Gulf of Darien (Urabá) also has very heavy rain in summer, but differs in its much drier winter and spring.

1(*b*). This tract is as remarkable for aridity as the last for excessive rain. The coastal strip, about 10 miles wide in the east but much wider round the Gulf of Maracaibo, between the Sierra Nevada de Sta. Marta and Margarita Island, and the islands off the coast, have the low total of below 20 inches, parts only 10 inches, and less than 20 rain-days, despite the mountain-range which backs the shore. The arid, sun-baked, cactus-strewn slopes and the bare and brilliant purple rocks of the gorges above La Guaira proclaim the dry climate; La Guaira has a mean annual rainfall of only 10 inches, most of it in the months June to August. The aridity is difficult to understand; a suggestion (by Garbell) is that it results from a slight off-shore component in the easterly winds, which thus descend to the coast, and also cause some upwelling of cool sub-surface water in the adjacent sea, both of which conduce to aridity; observations show that the sea off Venezuela is a few degrees cooler than most of the Caribbean.

1(*c*). The rainfall is normal in amount for the latitude, mostly over 80 inches a year, and in marked contrast to that of the last division. August to October is the driest but not a rainless period, which recurs with some regularity on the coast of British Guiana; the heaviest rains are in December–January and May–July, the latter being associated with the intertropical front which is then over the coast; the former perhaps results from the strong on-shore NE. trade. The total is ex-

cessive, 118 inches at Cayenne in this typically equatorial climate.

2. The llanos of Venezuela provide rather scanty climatic data, but experience indicates an almost rainless season from the end of November to the middle of March with clear skies and dry air. April brings a change; heavy clouds, thunder and lightning, usher in the rains, which last for 8 months while the equatorial trough is over the region; the rain is heaviest in June, July, and August, each with about 8 inches. Here and in other parts of Spanish America the rainy season is called 'invierno', winter, and the dry 'verano', summer, the popular language indicating the meteorological, not the astronomical, aspect.

3. The alternation of lofty ranges and deep valleys gives great diversity of rainfall, but the amount is large generally though less than on the Pacific coast so far as the inadequate records show. The west ranges have most, well over 200 inches in places; no season is dry, but the rain is less in winter, with exceptions, however; thus at Antioquia the months April to June and August to November have most rain, July being rather drier, and December to March is a dry season. Bogotá on the Andes, 8,730 feet above sea-level, has a normal equatorial régime with maxima in March to May and October to December, July being the least rainy month. The great valleys of the Magdalena and Cauca have abundant precipitation nearly everywhere since they open towards the NE. winds, but the upper Magdalena has less rain and poorer vegetation. Snow falls on the ranges above 14,000 feet. In the valleys the atmosphere is hazy almost to obscurity with smoke from bush-fires in the dry season, a common feature of tropical lands. The daily cycle of atmospheric vapour is prominent; in the night and early morning the valley-bottoms are often hidden in a long lake of white fog which dissolves after sunrise, and before midday clouds collect round the mountain-tops whither the valley-breezes have transferred the vapour; in the evening the clouds disappear and the valleys fill with mist again. But, exceptionally, round the S. Nevada de Santa Marta and on the neighbouring Caribbean Sea heavy rain with violent thunder tends to occur in the night.

TEMPERATURE

As is usual in low latitudes temperature is remarkably uniform through the year in all this region, the annual range being less than 5°, at Georgetown only 2°. Near sea-level it is hot, but not excessively so, 90° not being much exceeded; on the other hand, readings below 70° are rare. In the uplands the heat is moderated; Carácas, 3,400 feet above the sea with annual mean 69°, is naturally chosen as the capital of Venezuela, instead of its port La Guaira on the Caribbean coast, which is hot in all seasons and particularly stifling in late summer. Bogotá, the capital of Colombia, at 8,730 feet, has mean monthly temperatures ranging from only 57° in August, one of the driest months, to 59° in April, the rainiest.

The Guianas especially, owing to the combination of a constantly high temperature day and night (e.g. Georgetown, absolute maximum 92°, absolute minimum 68°, mean annual range 2°) with very heavy rainfall and very moist air and soil, are unhealthy, and a free exposure to the trade-wind, and good drainage, are essential to a European's comfort. Perhaps it was its fatal climate which won for French Guiana its chief fame as a convict settlement. Mangrove swamps fringe the coasts and creeks. On the west coast the Gulf of Guayaquil marks a change in temperature as striking as in rainfall, the cool of the Peru coast changing rapidly to normal equatorial heat in Colombia with day maxima about 90° and night minima never much below 70°.

In the Andes the usual classification by altitude is: tierra caliente from sea-level to 3,000 feet, with a mean annual temperature from 83° to 75°, luxuriant tropical vegetation, banana, sugar, and cacao plantations, and coconut groves; tierra templada from 3,000 to 6,000 feet, temperature 75° to 65°, suitable for maize and especially coffee, of which valuable crops are produced; tierra fria 6,000 to 10,000 feet, temperature 65° to 54°, where wheat, potatoes, and temperate fruits grow, but pasture predominates; paramos from 10,000 to 13,000 feet, too cold for trees and cultivation, temperature 54° to 43°; above 14,000 feet is perpetual snow.

CHAPTER XLII

BRAZIL. URUGUAY. PARAGUAY

The Amazon Basin

Rainfall. Both the NE. and the SE. trades find ready entry into the Amazon basin through the wide opening between the highlands of Guiana and east Brazil, as well as over the llanos of Venezuela. Ascending in the equatorial low pressures, especially when they reach the wall of the Andes which bars the way in the west, they give a very heavy rainfall—far heavier than that of the Congo basin, the corresponding region in Africa, for the relief of Africa tends to shut out the trade from the interior. The heavy rainfall makes the Amazon the mightiest river on the earth, and this reacts on the rainfall; for from the vast water-surface, especially in flood time, vapour is poured into the atmosphere to be condensed again as rain. Moreover, nearly the whole region is dense equatorial forest, and the transpiration from the trees adds greatly to the humidity of the air. It is remarkable that the basin has not the double maximum of rainfall in the year which might be expected near the equator.

The air which contains most vapour and provides the rain is maritime tropical in origin, brought by the NE. trade, but it has been modified by the heat and vapour acquired in its long equatorial passage into equatorial air before it enters the Amazon basin; the wind becomes NW. after crossing the equator. It fills the great lobe over the interior of Brazil behind the intertropical front as it advances to its farthest south in January (Fig. 157), and provides the heaviest rains. The tropical air of the South Atlantic, the SE. trade, is intrinsically dry and not a rain-giver, since only a small part of it has traversed the equatorial belt.

The vast region has not many good series of meteorological observations. Most are from the Amazon itself, and few from the Amazon above the confluence of the Rio Negro; they show a south hemisphere régime, the latitude being about 3° S. The annual mean exceeds 80 inches in much of the basin, this being the largest land in the world with such a total. Belém has 96

inches; the heaviest rains last from January to June inclusive, the rainiest months being February, March, April, and May, each with 10 inches or more; the rest of the year has drier weather, and September, October, and November have only about three inches of rain each. Even in the rainy season many mornings are clear, but clouds appear before noon, to culminate in a copious afternoon downpour frequently with thunder; 'before the rain' and 'after the rain' are ordinary expressions

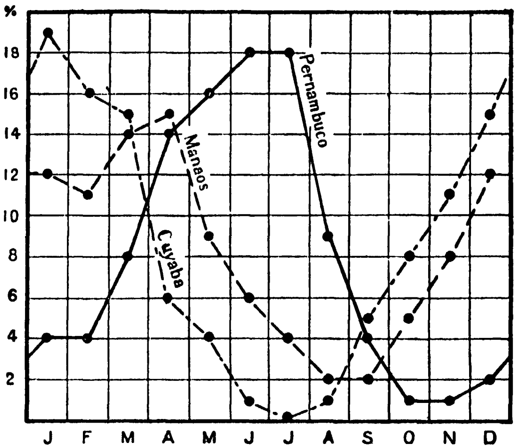


FIG. 164. Mean monthly precipitation.

of time. But sometimes it rains almost continuously for 24 hours or more, and a day without rain is rare. There are 251 rain-days and 63 days with thunder in the year.

In the middle of the basin the rainfall is less, and the dry season is longer and more pronounced than at Belém, lasting at Manáos from July to September, these months having about 2 inches of rain each (Fig. 164). The annual total is 79 inches, and thunder is heard on only 29 days. The less rainfall of the middle Amazon is reflected in the less luxuriant vegetation. Instead of the great unbroken rain-forest of the lower and upper parts of the basin there is much savanna, forming good pasture on the flat land near the river, but dry and almost useless bush, deep in dust in the dry season, on some of the higher ground, as south of Santarem, which is on the northern limit of the savanna of the interior of Brazil.

In the upper basin of the Amazon west of the confluence of

the Rio Negro rainfall increases again; Iquitos has probably more than 100 inches, August the driest month having nearly 5 inches, so that there is no dry season. In the montaña of Colombia, Ecuador, and Peru the orographic influence of the Andes facing the easterlies gives excessive rainfall in spite of the distance from the Atlantic, including, with the weakening of the winds, much instability rain, except in the short drier winter. The air is moist and the vegetation is a riot of dense rain-forest with rubber, cacao, cinchona, and other equatorial plants flourishing on the slopes up to 4,000 feet. The ranges above 12,000 feet are usually hidden in massive cloud. The eastern Cordillera is the main climatic divide, the plateau of the Andes conforming rather to the west coast than to the Amazon basin. The middle Amazon rises about 40 feet in the rainy season; at Obidos the river is lowest in November, highest in June. The Madeira is highest in April and May, lowest in September. In the Rio Negro basin the rains begin in February and the river is highest in June.

An interesting peculiarity on the lower Amazon is the bright lightning sometimes seen overhead without any thunder being audible.

Temperature. Temperature is high but not excessive. The east, favoured by the SE. trade, fresh from the sea and strengthened in the day by the sea-breeze, is appreciably cooler and less enervating than the interior. At Belém the annual mean is 78°, and the day's maximum is rarely above 90°, the absolute maximum being 95°:

Belém	*Mean daily max.*	*Mean daily min.*	*Mean daily range*
Month with largest range (Oct.) .	89	71	18
,, ,, least ,, (Mar.) .	86	73	13

Venezuela (mean temperature in September at La Guaira, 10·5° N., 83°) and the north-west of the Argentine are warmer (but only in their warmest months) than equatorial Brazil. The range of temperature is low and the nights are sultry (Belém has never recorded a temperature below 64°); during the rains the air is moist and the atmosphere that of a hot-house as in most equatorial lowlands; the mean relative humidity at Belém is 93 per cent. in the rains, 85 per cent. in the dry season. The coolest months on the Amazon are in the rains,

but the mean annual range of temperature is only about 3°. A more important relationship is that the dry season has cooler nights, though hotter days, than the rains when the excessive cloud and humidity check radiation. Manáos, with a mean annual temperature 80° and mean annual range 4°, is representative of the inner Amazon basin; the absolute maximum at Manáos is 102°, at Obidos 102°; the night minimum in the hottest months is about 75° (absolute minimum at Manáos 66°).

An interesting feature of the middle and upper Amazon basin is the 'Friagem', spells of a few days of remarkable cold with much cloud and occasionally rain. They occur in the winter half-year of the south hemisphere, and are incursions of polar air from beyond Cape Horn, possibly from Antarctica, which sweeps through the north of Argentina and the eastern lowlands of Bolivia into western Brazil as far as the Amazon. They are merely the west flank of extensive cold air-masses, the east portions of which move north over the east of the continent and the adjoining Atlantic Ocean, where they are a frequent cause of cold weather, low cloud, and rain (p. 500). Cold air-masses reach middle latitudes commonly enough in all continents; the remarkable feature in South America is that they reach the equator and bring such low temperatures. The cold air is led in by the cold front of a depression, the centre of which is far south; the west part of the front advances north between the highlands of Bolivia and of Brazil into equatorial Brazil, and the shallow cold air behind it is prevented from spreading west by the barrier of the Cordillera (which acts like the Western mountains of North America in confining cold waves from the north, p. 413). Even near the equator the temperature may fall 8°; a reading of 34° has been recorded at Cuyabá, 15° S. The front itself has massive clouds and often heavy rain, but the skies in the succeeding polar air are clear and the night temperatures are low; the friagem lasts for 4 to 5 days. Bates describes his experience of it:

. . . a cold wind, which blows from the south over the humid forests that extend, without interruption, from north of the equator to the eighteenth parallel of latitude in Bolivia. . . . The temperature is so much lowered that fishes die in the river Teffé, and are cast in con-

siderable quantities on its shores. . . . The wind is not strong but it brings cloudy weather and lasts from three to five days in each year. The inhabitants all suffer much from the cold, many of them wrapping themselves up with the warmest clothing they can get, and shutting themselves indoors with a charcoal fire lighted. . . . It was a bad time for my pursuit, as birds and insects all betook themselves to places of concealment and remained inactive (BATES, *The Naturalist on the River Amazons*).

SOUTH AND EAST BRAZIL. URUGUAY. PARAGUAY

Rainfall. These lands extend south from the equatorial belt and have the tropical climate of the south hemisphere with strongly contrasted rainy and dry seasons; summer is the rainy season in most of the region. But the rainfall of the coast has interesting peculiarities in both amount and season. To consider first the amount, from the equator to S. Luiz (lat 2·5° S.) the annual total of about 80 inches is high, though not notably high for the latitude, but beyond S. Luiz it falls away (with, however, large irregularities), to less than 20 inches on the north-facing coast approaching Cape S. Roque, and increases, again rapidly, to 40 inches near that cape. Orographic features which might explain the intervening low rainfall are lacking, but the coast concerned is merely the north-east end of the large arid tract in the interior of north-east Brazil (p. 502). From Cape S. Roque to Rio Grande do Sul, a distance of 2,000 miles, the amount of rain is more normal, averaging 40 to 60 inches a year, but rising to as much as 80 inches and falling to as little as 30 in small areas. The lowlands round the River Plate with about 35 inches are normal for the latitude, but southward most of the coast of Patagonia has less than 10 inches, and under 5 inches around Santa Cruz, an unusually small amount for the westerlies, in the rain-shadow of the Andes.

The rainfall is much heavier where mountains rise in the path of the trade. Thus Santos receives 88 inches, and even in winter has considerable precipitation; the rainfall increases rapidly up the steep slope of the Serra do Mar, to a maximum of 142 inches at Alto da Serra, 2,600 feet above the sea near the top of the range, where the driest month, July, has over 6 inches. On the railway from Santos to São Paulo 16 inches has fallen within 24 hours; 'the rain is so continuous and heavy that the railway company, which was laying a new line in the

Serra in the years 1897–9, state in their report that on 382 out of 975 work days, work had to be suspended on account of rain' (Voss). The lee slopes have much less rain, São Paulo only 52 inches a year, with less than 2 inches in July. Rio de Janeiro has the comparatively small total of 44 inches, but the strong on-shore winds are always moist; the damp heat in the rainy season, October to April, is enervating and unhealthy, but the rest of the year is by no means uncomfortable, thanks to the

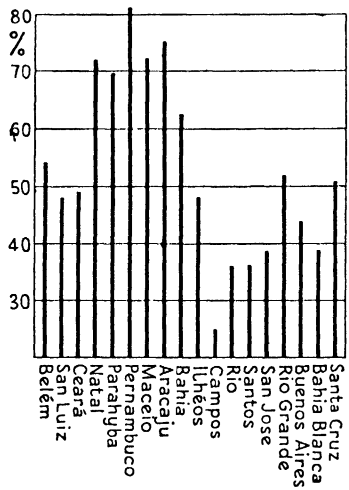


Fig. 165. Percentage of the mean annual rainfall received in the winter half-year.

lower temperature, drier air, and low rainfall. The sky is pleasantly clear (mean cloud about 4 tenths) in winter, but cloudy in summer, particularly in the afternoons. The temperature has never been known to exceed 99° or to fall below 50°—in striking contrast to Hong Kong, off the coast of China in almost the same latitude, where freezing temperatures sometimes occur.

The seasonal distribution of the rainfall of this littoral is remarkable; Fig. 165 shows the great differences in the proportions received in the winter and summer half-years. From the Amazon to Ceará the proportions are almost equal, as might be expected in equatorial latitudes (but the abnormality of a single maximum, and that in autumn, instead of the more

usual double maximum, is masked in the half-yearly totals). Beyond Ceará we enter the most abnormal régime for the tropics, the winter half-year having far more rain than the summer, in places more than 70 per cent. of the annual total; spring, and in less degree summer, are pronounced dry seasons but not rainless; this régime continues along the littoral beyond Bahia to about 14° S. Thence to 20° S. the winter and summer half-years' totals are similar, autumn and summer being the rainiest seasons, and this is the transition to the only region with a normal régime, the tract between 20° S. and 30° S. which includes Rio de Janiero and Santos, the most populous part of Brazil; here the summer half-year has far more rain than the winter, and summer and autumn are the rainiest seasons. South of 30° S. all the way to Staten Island the rain is fairly evenly distributed over the year, winter and spring being the driest seasons, not the rainiest—the normal régime for continental interiors and east coasts in the westerlies.

The interior of the vast area under consideration in this chapter, except Uruguay, has the normal tropical régime, a pronounced rainy season in summer and a dry but not rainless winter. Uruguay has its rain well spread over the year, with a tendency to an autumn maximum. It is described below.

The winter rains are better understood since daily synoptic charts have been drawn in detail, primarily for the needs of air navigation.[1] It is clear that polar air-masses, some of them derived from Antarctica itself, reach the south of the continent and many of them travel far north over it and the adjacent South Atlantic. They are led in by cold fronts, most of which extend far to the west and north from depressions travelling east over the Southern Ocean in the latitude of Cape Horn. Some of the surges take the form of shallow cold anticyclones, some cause anticyclones to build up in the sub-tropics both in central Argentina and on the Atlantic. The advancing front brings a large fall of temperature, and much precipitation which is heaviest where the cold air meets the warm SE. trade off the east of Brazil, and the amount is increased by the change in the alignment of the front when it approaches the highlands of Uruguay and Rio Grande do Sul which retard the cold air-

[1] e.g. see Coyle, J. R., *A practical Analysis of Weather along the East Coast of S. America*, 1940.

mass; the west of it, however, advances rapidly north on the flat plains of the River Paraguay and sometimes continues even to the Amazon (p. 496), while the east travels north over the ocean. Thus the front is bent (e.g. Fig. 166), and the east section tends to lie along instead of across the coast between Porto Alegre and Cape Frio, and to persist there against the highlands for some days, the cold winds blowing on-shore and giving orographic cloud and intermittent rain. North of Cape

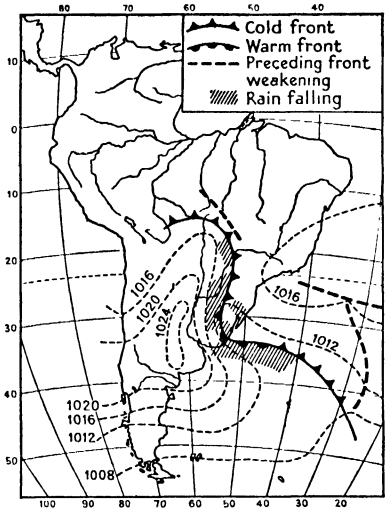


FIG. 166. Synoptic chart showing advance of cold front (based on *Aviation Meteorology of South America*).

Frio the fronts lie rather north-west to south-east and become more diffuse, but move more regularly though slowly. The interaction of the polar air, still cold, blowing here from the east, with the SE. trade moving almost parallel with it, together with the orographic influence (which seems to be large) gives heavy rains on the littoral; the fronts give little rain on this part of the ocean. This continues to Cape S. Roque, where the coast bends through a right angle and enters low latitudes, so that the winds blow along and not on to the shore; orographic effects are absent, and the frontal rains cease.

The surges of polar air which have been described are more massive and numerous, and advance farther, in the winter half-year; those of summer (and particularly of spring) give

rain only as far as 15° S. A dense and deep haze, under an inversion of temperature, sometimes covers the whole of the south-east coast of Brazil for several days in winter, and the flats are liable to have surface fog on clear nights; the bad visibility at such times is a serious obstacle for aircraft.

The summer maximum of rainfall between 20° and 30° S. is strongly marked, and though summer rain is normal for the latitude, the sudden change from the régimes on either side is difficult to explain. Possibly one factor is the closer proximity of the intertropical front with its rain in summer. Most of the summer rain falls in heavy instability showers in the afternoons; the winter rain is largely associated with the cold fronts described above.

The influence of the topography on cold fronts meeting the high ground north of the River Plate seems to be intensified by the vigorous interaction in central Argentina between polar and tropical air, which gives rise to many new and active wave-depressions, which move away south-east on the track shown in Fig. 172 into the Atlantic, where many of them develop great intensity. The polar winds from south-east and east in their south sectors are the well-known sudestras of the River Plate and the littoral south to Bahia Blanca, strong to a gale with thick low cloud, damp chilly polar air, and much rain. The damp air brought in by more moderate easterlies is liable to give fog over the coastal waters and the east of the Argentine.

In the interior the rainfall régime is that normal for the latitude; the periodicity is strongly marked. At Cuyabá (Fig. 164) the rains last from October to April; June, July, and August are almost rainless and the vegetation withers, to wake to new life in the beginning of October, and later the rivers overflow to form great marshes. The downpours may be very heavy; Asunción has often had more than 6 inches in a day, 8 inches in a day in January. In the dry season the sky is almost cloudless, but the atmosphere is often thick with dust and smoke from bush-fires; the fresh dry air is very welcome after the steamy heat, clouded skies, and thunderstorms of the rains. The seasons are similar in most of the region.

The famine region in the north-east of Brazil calls for special description. This region covers the interior of the State of

Ceará and extends west into Piauhy and south over the Sertas of the middle basin of the River Saõ Francisco in Pernambuco. Droughts have inflicted such lamentable losses and calamities on the scanty population that the Brazilian government appointed a commission many years ago to study the conditions and suggest possible alleviations. A native writer, quoted by Voss, says:

> As soon as the rains begin, the country, which until then had been desert, clothes itself with luxuriant vegetation, and the coffee and sugar plantations, which seemed almost ruined, recover with a speed unknown in other lands; in a short time the cattle are strong and fat again, thanks to the abundant fodder now at their disposal. But, unfortunately, the rains often fail for one or two years, and famine with all its terrors spreads over the hapless land. Cattle die by hundreds, all business is suspended, and long caravans of refugees make their way to the coast, strewing the route with the corpses of those who succumb to hunger and thirst.

Sievers mentions that over 25,000 such refugees died in 1878 in Fortaleza (Ceará). The most serious droughts occur in the interior, but at Fortaleza itself the annual rainfall has varied in the last 66 years from 96 per cent. above, to 66 per cent. below, the mean.

The driest parts of the scheduled area are semi-arid tracts of caatinga (dry thornwood) and bare rock. The mean annual rainfall is certainly low, less than 25 inches, and decreasing to less than 10 inches in the driest parts (8 per cent. of the whole according to F. W. Freise,[1] from whose work most of these details are taken). Such means, especially the lowest, are certainly inadequate for a tropical climate, though 25 inches should suffice for some useful forms of agriculture; the seriousness of the position results rather from the character of the rain and the nature of the soil. The year has a long, quite dry, dry season with cloudless skies, strong sunshine, and very dry air, from May to October, a period of light rain in spring, and a rainy season in the months December to April. But the rain is extremely variable both in amount and in time. In many years much of the 'rainy season' is rainless and the rest has more rain than the normal, the rain sometimes being so torren-

[1] Freise, F. W., *Der Mensch im Dürregebiet des Nordostens von Brasilien*, 1937.

tial, though a downpour rarely lasts an hour, that sudden flooding does as much damage as the more usual drought, eroding the soil, washing out crops, and blocking watercourses with detritus. The land-surface is unfavourable for a useful water economy; it is often baked hard and hot before the rain begins, and the loss by evaporation and run-off is excessive;

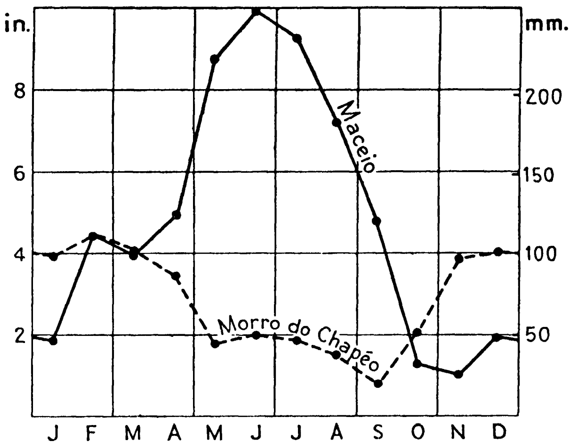


Fig. 167. Mean monthly rainfall.

the saline deposits make much of the water unfit for man or plants.

Temperatures are naturally more extreme than on the adjacent coast, the absolute extremes in the district being 107° and 53°, and 152° has been noted on the bare soil surface, but these are not specially remarkable. The winds are light and nearly always from an easterly point, SE. predominating.

Freise finds that in the last 100 years the most stricken areas, of considerable size, have had more than 50 'calamitous' years.

The causes of the abnormal climate are not obvious. One general consideration is that north-east Brazil is a continuation (beyond the littoral with its orographic rain) of the dry region of the South Atlantic under the SE. trade, the rainfall being the less inside the surrounding ranges. An explanation suggested by Freise is that the dry tract is so situated that it misses the full impact of both the cold-front rain of the coast, which is largely orographic and extends only about 100 miles inland, and the general summer rains of the interior of Brazil,

for the most part bounded by the intertropical front which is normally west of the dry area even in January (Fig. 157); thus the dry tropical air of the SE. trade is usually dominant, and it provides little rain. The dry season is May to September which is the rainy season on the coast (Fig. 167), and the worst droughts are in the months August to November. The

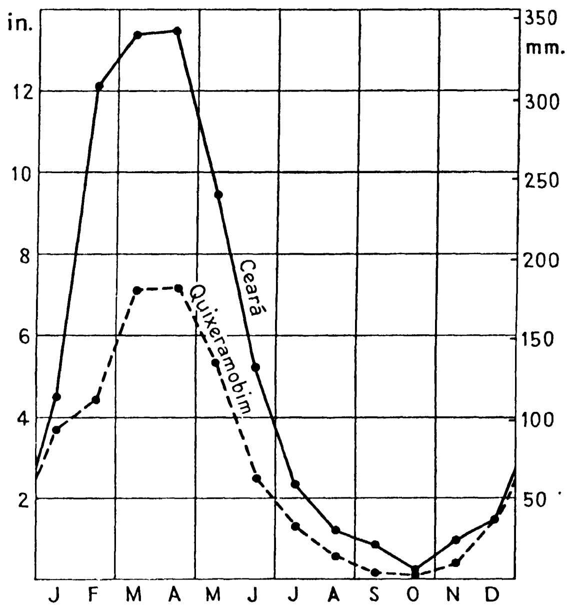


FIG. 168. Mean monthly rainfall.

summer rain results from the occasional eastward extension of the tropical rains of the interior. But in Ceará the dry season is the same in the interior as on the coast (Fig. 168).

Temperature. Summer is considerably warmer in the interior of this region than near the equator, but the dry season is much cooler, and invasions of polar air sometimes bring cold that is severe for the latitude. At Cuyabá October and November are the warmest months with mean temperature 81°, June and July the coolest with mean 73° and absolute minimum 50°. The Chaco Mission Station on the River Paraguay near the tropic has means of 84° and 64° in January and June, and absolute extremes 110° and 28°; Asunción 81° and 63° in January and June and absolute maximum 110°; thus the

plains of Paraguay have very hot summers. Winter becomes rapidly colder south of the tropic. On the plateau of Saõ Paulo frost is frequent and snow is not unknown; the best coffee of Brazil is produced here, though the plant is unable to stand much frost; but by avoiding the valley-bottoms (where the frost is keenest), and also the highest parts of the plateau, very suitable conditions are obtained. Even in the south of Minas Geraes the cold may be severe in the dry season; at Ouro Preto water occasionally freezes, and sugar-cane may suffer great damage. South of lat. 30° S. frost occurs even on the coast; at Monte Video it is rare, but temperature has fallen to 20°.

CHAPTER XLIII

THE ARGENTINE REPUBLIC

The Republic extends from lat. 22° to 55° S., 2,000 miles, and has many varieties of climate. Except in Patagonia the plains have hot summers and warm winters, the monthly means ranging from 75° in the south to 80° in the north in January, from 45° to 65° in July.

The Eastern Region (Fig. 169) has more than 35 inches of rain (80 inches in the hills of Misiones); summer and autumn are the rainiest seasons, but winter also has useful rain, an advantage for the cattle-ranches which are the best in the republic (Fig. 170). The Plate River gets a good deal of fog, the means being 53 days a year at Buenos Aires, 45 at Monte Video, most in autumn and winter.

The Central Region is distinguished from the Eastern by its longer dry season, which includes the period May to September; the mean rainfall, under 30 inches, also is less. The middle and south of this region have most of the wheat-lands of Argentina. The lower slopes of the Andes in the north-west are rainy and well forested. North of 28° S. the Eastern and Central Regions include the Chaco, a tract still largely wooded.

The Western Region as a whole is semi-arid to arid with little cloud and strong sunshine; its very varied topography includes mountain-ranges exceeding 5,000 feet and enclosing deep valleys and basins only a few hundred feet above sea-level. The rainfall is equally varied, ranging from 30 inches on

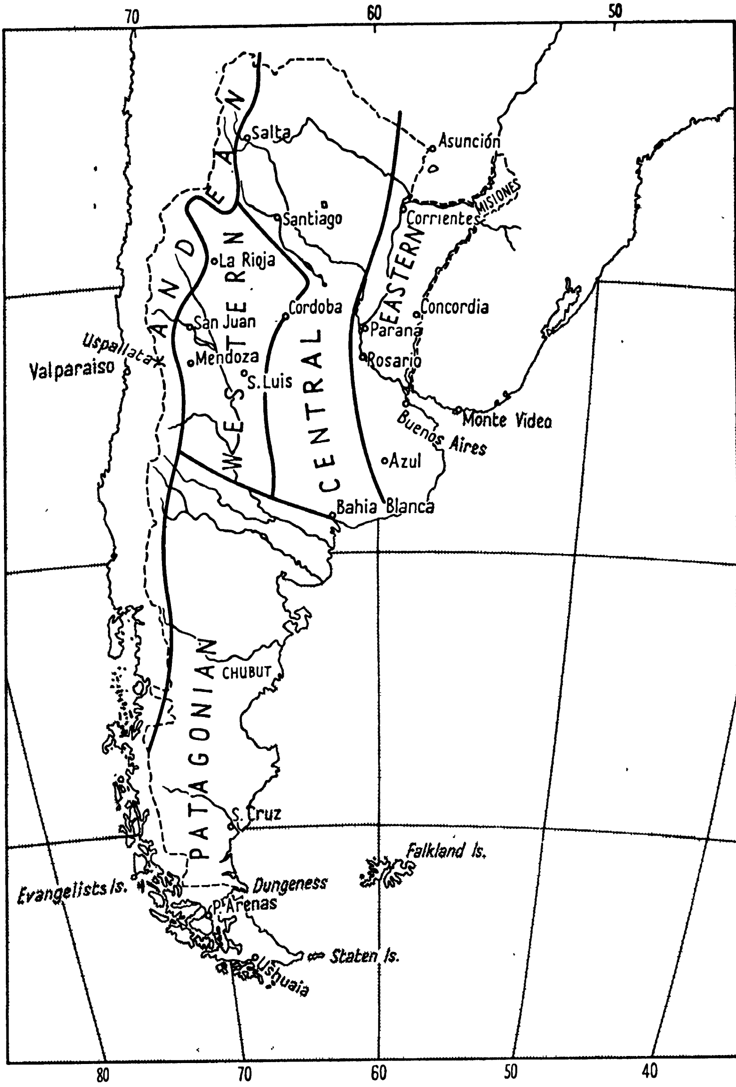


FIG. 169. Major climatic regions of Argentina.

the mountains to less than 10 inches in the depressions, which are mostly deserts (Mendoza has 8 inches, San Juan only 4 inches); the rain is very variable from year to year. Only occasional showers fall in the dry season, May to September, and the rains in the rest of the year are quite inadequate for agriculture without irrigation; the Salinas Grandes, salt-pans sel-

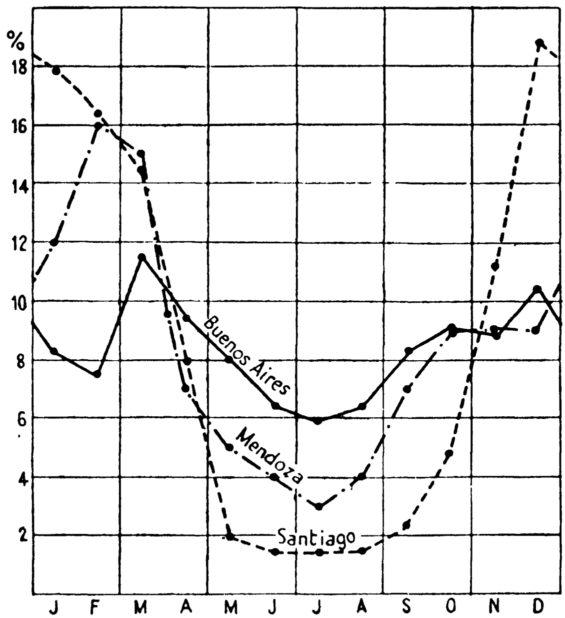


FIG. 170. Mean monthly rainfall (percentage of annual total).

dom filled with water, are expressive of the aridity. The summers are very hot, the winters cool with many cold days. This Western Region is thus in strong contrast to the well-watered and well-wooded north-east of the republic, to Patagonia, much of which has an equally low rainfall but is a bleak and cold land, and to central Chile (Fig. 171). It has the most continental climate of the continent.

The Andean Region has ranges nearly all of which rise high above 10,000 feet. The north is almost rainless, remarkably dry and bare for a mountainous region; it is part of the belt of low rainfall that extends from Patagonia to the north of Chile. Only the highest summits have perpetual snow, for the scanty

precipitation and the powerful sunshine keep the snow-line as high as 21,000 feet near the tropic, this being one of the highest snow-lines on the globe.

South of 30° S. the conditions worsen rapidly, and the passes are scenes of wild winds and weather; observations are available from the Uspallata Pass, 12,000 feet, which is crossed by aircraft on the service between Buenos Aires and Santiago (Chile), and is the difficult stage in the flight. The winds are nearly always west, often blowing through the gap at over 90 miles an hour even in the absence of frontal disturbances, and their irregularity, turbulence, and up- and down-draughts add to the confusion; during the passage of fronts the whole area, mountains and pass, is hidden in deep masses of cloud, and snow may fall with little intermission for a day or two even in summer, making navigation impossible; rain is rare at these altitudes. In settled weather the winds moderate and visibility is extremely good, but convection-cloud, cumulus and cumulonimbus, build up in the afternoons, with frequent showers in the pass as well as on the mountains. We have less information about the high Andes farther south, but it is probable that the weather is more continuously stormy than round Uspallata Pass.

Thus the northern regions differ much in their rainfall; in general it decreases very rapidly from east to west, from more than 35 inches in most of the Eastern to much less than 10 inches in much of the Western, which implies a deterioration from well-watered grasslands to an arid interior where the streams wither away in the bare sand. Most of the rain falls in summer, much of it in the many thunderstorms of thermal depressions, moving from south to north (Fig. 172), but the summer excess is not very large in the east, and Buenos Aires has more rain in autumn than summer. The seasonal percentages are:

	Spring	*Summer*	*Autumn*	*Winter*
Buenos Aires . .	26	26	29	19
Rosario . . .	29	31	28	11
Santiago . . .	19	53	24	4
Cordoba . . .	25	45	26	4
Mendoza . . .	25	37	27	11

Large totals in 24 hours have been reported at many stations, e.g. 7·0 inches at Buenos Aires, 6·4 inches at Paraná.

The following table indicates the variability of the annual totals:

ANNUAL RAINFALL (inches)

	Mean	*Highest record*	*Lowest record*
Buenos Aires	37	80	21
Cordoba	28	40	18
San Juan	4	7	0·2

The hazard of drought is very serious in the republic, which is dependent on agriculture; the Central Region as well as the West have suffered frequently. A drought may last 2 or even 3 years; San Juan has had a spell of 671 days without measurable rain, Cordoba 103 days. Lack of rain is the more calamitous under the fierce, almost continuous, sunshine. Humidity and cloud, like rainfall, decrease rapidly towards the west:

	Mean relative humidity, %, 1400		*Mean monthly cloud, tenths*		*Mean annual sunshine*
	Highest	*Lowest*	*Highest*	*Lowest*	*hours*
Buenos Aires . .	79 (July)	61 (Jan.)	6 (June)	4 (Jan.)	2,576
Cordoba . . .	54 (Mar.)	37 (Aug.)	5 (Nov.)	4 (Aug.)	2,643
San Juan . .	60[1] (June)	43[1] (Nov.)	3 (June)	3 (Sept.)	2,965

[1] Mean for 24 hours.

The following table illustrates the temperature conditions:

	Alt. feet	*Mean annual range*	*Mean daily range Jan.*	*Mean daily range July*	*Absolute maximum*	*Absolute minimum*
Eastern		°*F.*	°*F.*	°*F.*	°*F.*	°*F.*
Buenos Aires . .	89	25	22	15	104	22
Paraná . . .	210	26	24	17	113	25
Central						
Santiago . .	660	25	28	21	115	27
Cordoba . .	1,437	23	21	22	111	16
Western						
San Luis . .	1,686	27	28	24	106	19
Mendoza . .	2,625	28	30	24	109	15

The range is larger in the western regions than near the sea, the highest temperatures being considerably higher and the lowest somewhat lower. Even the extreme north of the republic has recorded slight frost in winter, and in the centre and south frosts may be severe enough to damage crops; Santiago has on the average 2 days with snow, Mendoza 1 day a

year, but the snow soon melts. The highest temperature record is 116° at Chilca (in Santiago del Estero), the lowest −27° in the south of Chubut (in the Patagonian climate province), and here, and everywhere to the south, frost may occur even in the warmest month. Buenos Aires has had frost in all the months April to October.

The South Region, Patagonia (Fig. 169), is full in the belt of the westerlies. It is the coldest part of the republic, most of it

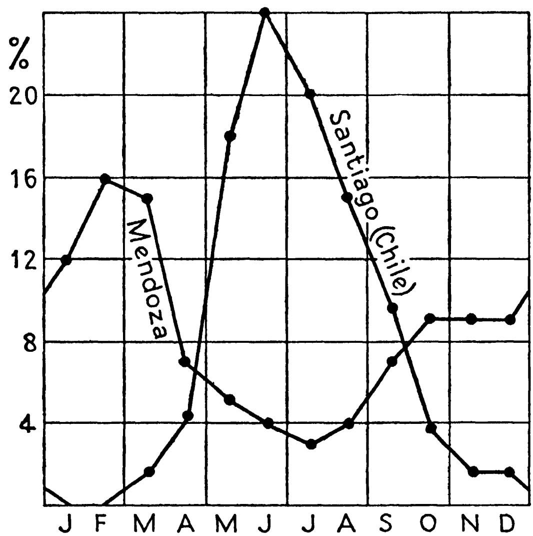


FIG. 171. Mean monthly rainfall, percentage of yearly total.

being more than 2,000 feet above the sea; the mean temperature (sea-level) falls in January from 75° in the north to 55° in the south, in July from 45° to 35°. The summers in the south are cool, bleak, and inclement, the winters cold, though intense cold is precluded by the narrowness of the land, the littoral being even warm for its latitude. Ushuaia is liable to have frost in all months, but the temperature may rise to 80° in summer.

Being in the rain-shadow of the Andes Patagonia has low precipitation, 20 inches a year round Bahia Blanca and only 5 inches on the arid littoral of Chubut and Santa Cruz, but increasing in the extreme south to over 20 inches, and still more in the west where the Andes raise the totals, most in the

province of Neuquen, the Switzerland of Argentina; the precipitation is well distributed over the year. Dungeness and Punta Arenas have only 70 rain-days a year; W. winds often give almost cloudless skies, in strong contrast to the persistent thick low cloud on the windward west coast of Chile. Snow falls on 5 days a year at Dungeness, 40 days (in all months) at Ushuaia, 60 days on Staten Island.

Pressure-systems and Winds. Pamperos

The south of the continent projects into the stormy westerlies and has its full share of cyclonic activity. Most of the primary depressions pass on a generally west–east track south of Cape Horn (Fig. 172) but many cross Tierra del Fuego and some originate in the sub-tropical Pacific and cross the Andes (few, however, north of lat. 40° S.). Their speed is remarkable; the mean in the Falkland Islands is estimated at 25 kt. in summer and as much as 35 kt. in winter. Many have elongated troughs extending far north, some even to the north of the Argentine, which give cyclonic weather over the whole country; their cold and occluded fronts often sweep across the south of Chile, all Argentina, and into Brazil, and their own direct weather-effects are intensified by secondary depressions which tend to develop on them between 45° and 30° S. on the east of the Andes and travel north-east, and others in the north of the republic which move south-east; they may become very vigorous as they approach the coast, and give strong SE. winds (Sudestadas) with bad weather and much rain. The persistently strongest winds, however, are in the south, and their general direction is from the west, but they are deflected to follow the numerous tortuous channels, a source of difficulty and danger to ships passing through the Strait of Magellan; gale force is recorded on 80 days a year at Evangelists Island.

A manifestation of the cyclonic conditions in the northern provinces and particularly round the River Plate is the 'Pampero sucio', a violent squall at the cold front of a depression moving eastward. The polar air comes from between south and west; it is sometimes preceded by a roll of cumulus and followed by heavy cumulo-nimbus with torrential rain and

thunder, and often by clouds of dust. The main squall may last less than a quarter of an hour, but the wind continues strong, but steadier, for some hours. Buenos Aires has about 12 pamperos a year, most in spring and summer, Monte Video 16, the River Plate 20; they are fierce storms and shipmasters have good reason to know them. Behind the squall the polar air is cool, the sky clear, and the wind moderate—weather called 'pampero' locally; the pampero sucio is of the same type as the Southerly Burster of New South Wales. In strong contrast to it, and often preceding it, is the Zonda of the Western Region, a strong W. wind, hot, dry, and dusty, which acquires its föhn character in its descent from the Andes; it is most frequent in spring.

In addition to the frontal disturbances, shallow thermal depressions ('heat lows') develop on the hot central plains in summer, and give heavy thundery rain as they travel slowly north. The plains are exposed to invasions of hot tropical air from the north, moist, sultry, and enervating. The level of the shallow River Plate is remarkably sensitive to strong winds, those from north-west causing a sudden fall of several feet.

CHAPTER XLIV

MEXICO. CENTRAL AMERICA. THE WEST INDIES

FEATURES of this large area as a whole are described first, some details of the larger divisions follow, and finally an account of hurricanes.

The Caribbean Sea and the Gulf of Mexico are filled with the very warm waters of the North Equatorial Current of the Atlantic, which become still warmer in their circuit of the basin so that the surface temperature exceeds 80° all the year. The West Indies and the shores of the mainland enjoy a uniformly hot and humid climate, with heavy to very heavy rainfall and yet abundant but not overpowerful sunshine, which produces the rich green vegetation from strand to mountain-top that makes these lands a tropical paradise.

The region lies between the sub-tropical high pressures of the Atlantic and the equatorial low pressures all the year, so

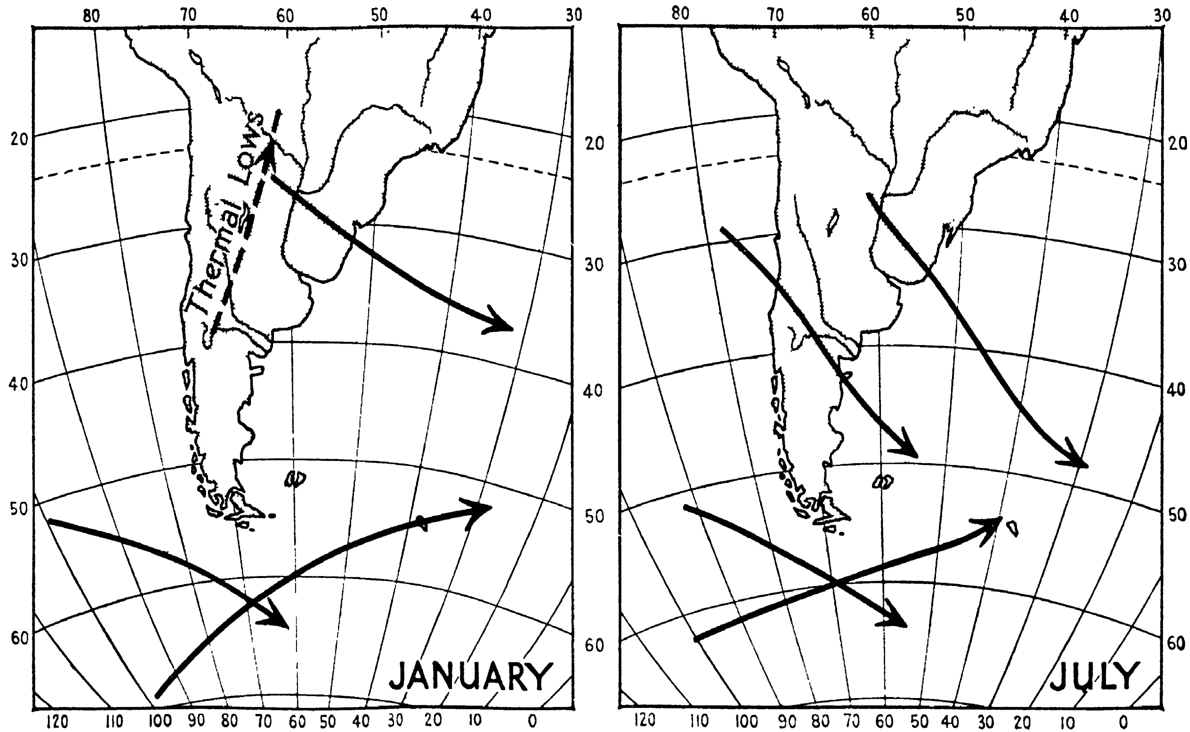


FIG. 172. Generalized tracks of depressions (based on *Aviation Meteorology of South America*).

that the prevailing and almost constant wind is the trade, bringing maritime tropical air from the east. The islands are too small to cause much local modification, except the larger ones which develop regular land- and sea-breezes; the sea-breeze often attains 12 miles an hour, but the land-breeze is light. The winds are more complex in Mexico; on the west coast the prevailing winds are NW. all the year, blowing down the Gulf of California. In summer the east coast has monsoonal E. and SE. winds; but in winter the influence of the North American continent is felt, for the off-shore winds (northers) of Texas continue down the east of Mexico to Yucatan, at times far beyond, and their cold is keenly felt even in the Gulf of Tehuantepec and Central America; the thermometer falls occasionally to freezing-point in the north of the Gulf coast of Mexico, and Central America is liable to frost in winter at altitudes above 4,000 feet. The isthmus of Tehuantepec has strong and almost constant N. winds in winter which give heavy rain on the north coast but are dry when they reach the Pacific; these 'nortes' (called also papagayos, and in the Gulf of Tehuantepec, tehuantepecers) may quickly send the temperature down 10° or 15° for a couple of days, a severe visitation in these latitudes, and they can blow with gale force in the Gulf, and sometimes as far as Costa Rica, ushered in by heavy rain-squalls. Together with less prominent winds between NE. and NW. they predominate in winter on the Pacific coast of Central America; in summer strong monsoonal winds between SE. and SW. are dominant.

Jamaica, Cuba, and the Bahamas, but not Haiti and the islands to the east, have cool winds from the north, a continuation of the cold waves of the United States.

In the Caribbean Sea and its many islands no month is rainless, but winter has much less rain than summer, which is the very rainy season (Fig. 173); the northern islands have two maxima of rainfall, in May or June and October or November, and appreciably less in July and August. In winter the subtropical anticyclone of the North Atlantic is farthest south and the equatorial trough has retreated almost to the equator on the Atlantic, and much farther, even to the tropic of Capricorn, in South America, so that the warm dry subsiding air of the inner zones of the anticyclone feeds the NE. trade of the Carib-

bean, and rainy disturbances due to frontal interaction with moist equatorial air are rare. Most of the rain in winter is associated with cold fronts from North America travelling slowly south-east over the region; it falls in short showers on the more sheltered south coasts, but is heavier on the wind-

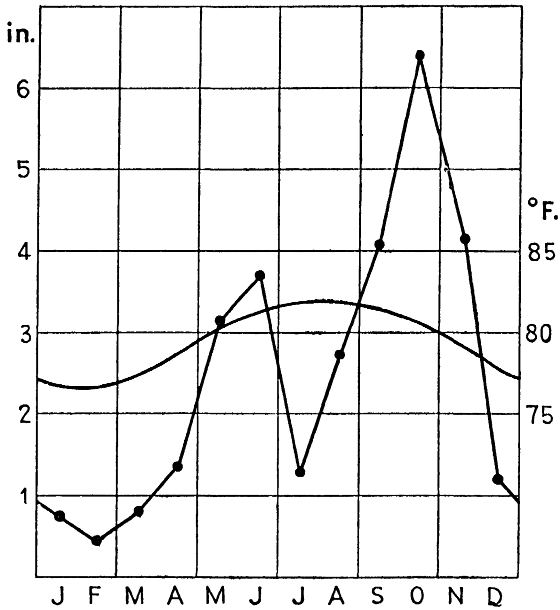


FIG. 173. Mean monthly temperature and rainfall, Kingston (Jamaica).

ward slopes, which are also liable to get rain of long duration from the trade-wind (H. E. Davis).

The equatorial trough returns north with the sun; in summer the intertropical front is near the north coast of Venezuela and about 8° north of the equator in the North Atlantic; the sub-tropical high pressures of the North Atlantic have shifted some distance north-east. The Caribbean is thus outside the zone of the stable, subsiding, tropical air, and the trade-wind is warmer and damper than in winter; frontal interactions between it and hot, moist, equatorial air are frequent. Convection over the hot surface adds to the rainfall (much of which falls in heavy showers in the afternoons, often with thunder) especially in autumn when thunderstorms give torrential downpours; more potent are the hurricanes (p. 519) of that season in

increasing the totals in the islands they devastate. In these storms more than 20 inches of rain has fallen in 24 hours, and violent floods sweep down from the mountains, tear up the country and carry away roads and bridges. Owing largely to the irregular hurricane rains the annual totals in Jamaica and other islands in the hurricane area are notably variable; Kingston had 86 inches in 1933, only 9 inches in 1914.

The local relief gives very different rainfalls in the mountainous islands, position on windward or leeward side being the controlling factor. In Mexico and Central America the east coastal belts and the east slopes of the mountainous interior have far more rain than the Pacific side, in many parts more than twice as much.

The West Indies

Jamaica shows the strong topographical influence on rainfall; Kingston on the south coast under the lee of the mountains has 31 inches, Port Antonio on the windward north-east coast 137 inches, Blue Mountain Peak, altitude 7,400 feet, 175 inches, and Moore Town, 591 feet above the sea on the north-east slope, 222 inches. In March, the month with least rain, Port Antonio has nearly 5 inches, Blue Mountain Peak 8 inches, so that no season is dry; but at Kingston the months December to April, with only about 1 inch each, are a distinctly dry season. The Windward Islands, being farther south, have a long rainy season from June to December under the influence of the intertropical front. Exceptionally dry islands are Curaçao (23 inches a year) and the other islands off Venezuela as far as Margarita (10 inches) whose arid slopes proclaim the scantiness of the rainfall; they share the low rainfall of the mainland (p. 490), and are liable to serious droughts. The summer rain tends to fall in heavy afternoon thunderstorms; in winter the rain is lighter, sometimes a drizzle, and lasts longer, with a smaller proportion in the afternoon. Excessively rainy spells occur; the east of Jamaica had 135 inches in the 8 days 4–11 November 1909, and in the same period another area recorded 96 inches in 4 days.

The islands enjoy a remarkably uniform temperature and high humidity, thanks to the warm seas and the low latitude.

In the Greater Antilles in the north the mean monthly temperature at sea-level ranges from about 70° in January to 82° in August; at Kingston, Jamaica, the mean minimum of the year is 62°, the mean maximum 94°, and the absolute extremes are 57° and 98°. Barbados and the other southerly islands are equally warm in summer, and much warmer in winter with a January mean about 77°, making the mean annual range only 4°; the mean annual extremes are about 66° and 90°. The thermometer rarely rises above 100°, or falls below 60°, at sea-level. The winters are coolest in the islands nearest North America from which polar air reaches them. Tropical and subtropical products including bananas, sugar, citrous fruits, and at high elevations coffee, flourish, and in the southern islands cacao. The northern islands are a delightful health-resort in winter, but too hot and damp in summer.

Mexico

In Mexico the west coast, the interior plateau, and the east coast, must be distinguished, as well as the altitude zones; tierra caliente from sea-level to 2,000 feet, tierra templada up to 6,000 feet, and tierra fria over 6,000 feet (see p. 492). Most of the plateau is above 6,000 feet, and is therefore in the upper tierra templada or lower tierra fria zone. The east, windward, coast has moist air, and, especially in the south, heavy rainfall, and is clothed with luxuriant tropical forest, except the lowlands of Yucatan where the mean annual total decreases northward to 20 inches on the north coast (and the rain sinks at once through the very permeable limestone surface, and is lost to the vegetation), and the delta of the Rio Grande del Norte which has about 35 inches. The west coast presents a great contrast, for the north and the adjoining plateau are largely desert, a continuation of the deserts of Arizona, the constant NW. winds giving little rain; this desert region is, in summer, the hottest part of Mexico. The north and south sides of the isthmus of Tehuantepec also illustrate the difference in rainfall between windward and leeward coasts, the north having over 80 inches, the leeward south less than 40 inches. All the plateau, enclosed by its mountain rim, suffers from a deficiency of rain, the yearly total being under 10 inches in the north. The mean temperature here is, of course, much lower than on

the coasts, but the summer days can be much hotter, and the winter nights far colder on the plateau for frost and snow are not unknown at Mexico City, 7,500 feet above the sea. The monthly means at Mexico City are about 17° lower than on the Gulf coast, but the mean annual range is about the same. When the cold waves from North America sweep down the east of Mexico in winter snow has fallen on the normally hot coast as far south as Tampico.

Central America

The mountainous interior rises to heights which enjoy a temperate, but rainy, climate throughout the year; the tierra templada in Costa Rica and Guatemala is famous for coffee. But the coasts are hot, damp, and unhealthy even by equatorial standards.

The east, windward, coast and slopes of the mountains get more than 100 inches of rain a year in many places, Greytown, Nicaragua, 260 inches (November 36 inches, March, the driest month, more than 6 inches); the Pacific coast has less, 60 to 80 inches, much of it in thunderstorms. The dry season is December to April, but on the east coasts the season is dry only in comparison with the rest of the year with its excessive rain and hot vapour-laden air; most of Central America has two maxima of rainfall in the year, round May and October.

The Republic of Panama including the Canal Zone, being in the lowest latitudes (between 10° and 7° N.), has the most equable, almost equatorial, temperatures, the mean near sea-level being about 80° in every month, and the mean annual range less than 2°; the daily maximum is rarely above 90° or the minimum below 70°. The central part of the isthmus with the Canal Zone is low ground, tierra caliente, under 2,000 feet, but the mountains in the west and east rise into tierra fria reaching over 9,000 feet in the west. The narrowness of the isthmus and its position between the hot waters of the Caribbean Sea and the Pacific Ocean conduce to the small range of temperature and also to the very high humidity and heavy rainfall, 130 inches a year at Colon on the windward north coast, 70 inches at Balboa Heights on the Gulf of Panama, and much more, probably about 200 inches, on the north slopes

of the densely forested ranges. On the Caribbean side the rainfall is heavy all the year except in January to March when the intertropical front is farthest south and the air of the constant NE. trade is fairly stable; the change in January from the rains to the much drier season, and to the rains again in April, is abrupt. On the Pacific side also the least rainy months are January to March which form an almost dry season. In the rest of the year the proximity of the intertropical front is a major factor in the heavy rains, and the winds are more variable:

COLON (NORTH COAST); WIND DIRECTIONS, MEAN PERCENTAGE FREQUENCIES

	N.	*NE.*	*E.*	*SE.*	*S.*	*SW.*	*W.*	*NW.*
Jan. . .	61	28	1	1	0	1	2	6
July . .	22	14	4	12	9	9	19	11

The Canal Zone had an extremely bad medical reputation in former times, which seems to have been justified by the high disease and mortality rates during the early attempts to dig a canal. But rigorous and extensive application of sanitary, especially anti-malaria, measures by the American engineers of the present canal worked a wonderful improvement, and the zone is now notably healthy, and even pleasant in winter, for a region so near the equator.

Costa Rica resembles Panama, but more of the interior consists of high mountain and plateau rising to over 10,000 feet in places.

HURRICANES

The climate of the West Indies is particularly pleasant for the tropics, but it suffers from one great disadvantage, a liability to hurricanes. These violent tropical cyclones generally originate east of the islands, many of them probably as far east as the Cape Verde Islands, and may work destruction on one island after another in their westward course. Some tracks are shown in Fig. 174. Not only the West Indies, but also the east of Central America south to the Mosquito Coast, and the Gulf and south-east coasts of the United States, are within their reach; Costa Rica, Panama, the north coast of South America, and (with very rare exceptions) Trinidad are outside the hurricane region. In the hurricane which devastated Galveston on 8 September 1900:

The loss of life in the city alone was 3,000, and throughout the whole of Texas it probably exceeded twice that total. Scarcely a house was left standing in the hitherto thriving city, the grain elevators were all overturned, the waterworks a complete wreck, and ships of all sorts were driven on shore. The land is low near Galveston; the water piled up by the storm swept completely over it, and torrential rain added to the distress. Eight ocean-going

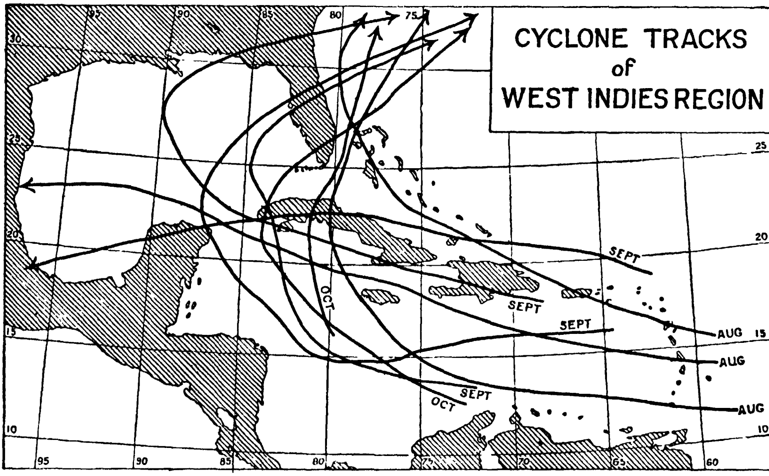


FIG. 174. Generalized tracks of hurricanes.

steamships of considerable tonnage were borne far inland. The *Kendal Castle* was over eight miles inland when the gale took off (*Pilot Chart*).

But most hurricanes recurve towards the north-east well to the east of the meridian of Galveston. In the 50 years 1887–1936 the region had 181 storms of full hurricane intensity, an average of nearly 4 a year:

Jan.	0	Apr.	0	July	13	Oct.	35
Feb.	0	May	0	Aug.	51	Nov.	6
Mar.	0	June	10	Sept.	66	Dec.	0

A district may escape visitation for some years, and then suffer severely more than once in a single season. Jamaica had 14 hurricanes with winds exceeding 60 miles an hour in the last century.

Gales, most of them northers (p. 412), of less than hurricane

intensity, are not infrequent in the Gulf of Mexico in the winter half-year.

Similar hurricanes, but most of them covering a smaller area, spring up on the Pacific off Central America and Mexico between Costa Rica and Point Eugenio (Lower California); they are called Coronazo de San Francisco. Their normal tracks are towards north-west or north and many strike the coast. In 19 years 32 such storms, with winds of 55 knots or more, were reported:

Jan..	. 0	Apr..	. 0	July.	. 5	Oct..	. 8
Feb.	. 0	May.	. 0	Aug.	. 6	Nov.	. 1
Mar.	. 0	June	. 1	Sept.	. 11	Dec..	. 0

Heavy local thunderstorms with strong squalls, known as Chubascos, are also frequent on these west coasts in the rainy season.

CLIMATIC MEANS

TEMPERATURE (°F.)

	Alt. feet	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year	Range
The West Coast, south of the Equator															
Lima	364	71	**72**	72	69	65	62	60	*60*	60	62	64	67	65	12
Callao	coast	69	70	**71**	70	67	65	63	*62*	62	64	65	69	67	9
Arica	95	70	**71**	70	67	64	62	60	*59*	61	62	65	67	65	12
Iquique	30	70	**70**	68	65	63	62	61	*61*	62	63	66	68	65	9
Antofagasta	308	70	**70**	68	64	61	59	*57*	*57*	59	61	64	67	63	13
Valparaiso	135	**64**	64	63	59	57	54	*53*	54	55	57	60	63	59	11
Santiago	1,706	**69**	67	63	57	52	47	*46*	49	53	58	62	67	57	23
Valdivia	16	**62**	62	59	54	50	47	*47*	47	49	53	56	59	54	15
Evangelists Island	180	46	**47**	45	44	43	40	*38*	40	39	41	42	44	42	9
The Andes Plateau															
Quito	9,350	58	55	*55*	55	55	55	55	55	**55**	55	55	55	55	0·4
La Paz	11,916	51	51	51	50	48	45	*44*	46	49	51	**53**	52	49	9
El Misti	19,193	**21**	21	19	18	15	*14*	15	15	15	19	21	20	18	7
Sucre	9,350	*55*	55	**57**	55	53	50	*49*	53	56	56	**58**	57	54	9
South America, north of the Equator															
Bogotá	8,727	58	58	**59**	59	59	58	57	*57*	57	58	58	58	58	2
La Guaira	coast	*78*	78	79	80	81	82	81	83	**83**	83	81	79	81	5
Carácas	3,418	*65*	67	69	71	**71**	70	70	70	70	70	69	67	69	6
Bolivar	125	*79*	81	82	84	**84**	82	81	82	83	83	82	80	82	5
Georgetown	6	*79*	79	80	81	80	80	80	80	81	**81**	81	80	80	2

	Alt. feet	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year	Range
Brazil. Uruguay. Paraguay															
Belém	42	78	*77*	78	78	79	79	*78*	79	79	79	**80**	79	78	3
Manáos	144	79	78	*78*	79	79	79	80	81	**82**	82	81	80	80	4
Trinidad (east Bolivia)	774	81	82	79	79	79	*74*	78	75	77	82	81	**82**	79	8
Recife (Pernambuco)	97	**82**	82	81	80	79	78	*76*	76	78	80	81	81	80	6
Bahia	154	80	**80**	80	79	77	76	74	*74*	75	77	78	78	77	6
Cuyabá	541	80	79	79	79	75	73	*73*	77	80	**81**	81	80	78	8
Rio de Janeiro	201	78	**78**	77	75	72	70	*69*	70	70	71	74	76	73	9
São Paulo	2,690	69	**69**	68	65	60	59	*58*	59	61	63	65	68	64	11
Asunción	456	**81**	80	78	72	67	*63*	64	66	70	73	76	80	72	8
Monte Video	72	**73**	71	69	62	56	51	*51*	51	55	59	64	69	61	22
The Argentine Republic															
Santiago	623	**83**	81	77	70	63	*56*	57	61	67	72	77	81	70	27
Cordobá	1,388	**74**	72	69	62	56	*50*	51	53	59	63	68	72	62	24
Paraná	210	**79**	78	74	66	60	53	*53*	56	60	64	71	77	66	26
Mendoza	2,625	**75**	73	69	60	53	47	*47*	51	57	63	69	73	61	28
Rosario	98	**77**	75	71	65	58	52	*52*	54	59	63	69	74	64	25
Buenos Aires	89	**74**	73	69	62	55	50	*49*	51	55	60	66	71	61	25
Bahia Blanca	95	**75**	72	68	61	54	48	*48*	50	54	59	66	72	61	27
Santa Cruz	39	**59**	58	55	48	41	35	*35*	38	43	49	53	56	47	24
Punta Arenas	92	**53**	52	48	44	41	36	*36*	38	41	45	48	51	44	17
Ushuaia	26	49	**50**	47	40	36	33	*32*	34	38	44	45	48	41	18
Mexico. Central America. The West Indies															
Mazatlan	256	67	*67*	67	70	75	79	81	**82**	81	80	74	69	74	15
Manzanillo	26	75	74	*74*	76	79	82	**83**	83	81	81	79	77	79	9

TEMPERATURE (°F.) (*continued*)

Mexico. Central America. The West Indies (continued)

	Alt. feet	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*	*Range*
Mexico City	7,487	*54*	57	61	63	**65**	64	62	62	61	59	57	55	60	11
Vera Cruz	52	*70*	71	74	78	81	**81**	81	81	80	78	75	71	77	11
Belize	125	*79*	81	82	84	**84**	82	81	82	83	83	82	80	82	5
San José	3,760	66	67	68	69	**69**	68	68	67	68	67	67	*66*	67	3
Colon	36	80	81	81	**82**	81	81	81	81	80	*80*	80	81	81	2
Balboa Heights	118	78	79	80	**81**	79	79	79	79	79	78	*77*	78	79	4
Havana	62	*71*	72	74	76	79	80	82	**82**	81	79	75	73	77	11
Kingston (Jamaica)	110	77	*77*	77	79	79	82	**82**	82	81	80	79	78	80	5
Bridgetown (Barbados)	181	*77*	77	77	79	80	80	80	**80**	80	80	79	77	79	3
Port of Spain (Trinidad)	72	*76*	77	77	79	79	79	79	79	**80**	80	79	78	78	4

PRECIPITATION (inches)

The West Coast, south of the Equator

	Alt. feet	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*
Lima	364	0·1	0	0	0	0·1	0·2	0·3	0·3	0·3	0·1	0·1	0	1·5
Arequipa	8,040	1·3	**1·9**	0·5	0·1	0	0	0·1	0	0	0	0	0·1	4·0
Arica	95	0	0	0	0	0	0	0	0	0	0	0	0	0
Iquique	30	0·1	0	0	0	0·1	0	**0·7**	0·3	0·2	0·1	0	0	1·5
Antofagasta	308	0	0	0	0	0	0·1	**0·2**	0·1	0	0·1	0	0	0·5
La Serena	33	0	0	0·1	0	**1·3**	1·2	1·1	0·4	0·1	0·1	0	0	4·3
Valparaiso	135	0·1	*0*	0·3	0·6	4·1	**5·9**	3·9	2·9	1·3	0·4	0·2	0·2	19·9
Santiago	1,706	*0*	0·1	0·2	0·6	2·4	**3·3**	2·8	2·1	1·3	0·5	0·2	0·2	13·7
Valdivia	16	*2·7*	2·8	5·5	9·5	13·9	**18·1**	15·6	13·0	8·4	5·0	5·0	4·0	103·5
Evangelists Island	180	8·8	8·5	**11·4**	10·0	7·7	*6·9*	7·9	7·8	7·7	7·8	7·5	8·5	100·5

	Alt. feet	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
The Andes Plateau														
Quito	9,350	4·2	4·3	5·2	**7·4**	5·0	1·5	*0·9*	1·5	3·0	3·7	3·8	3·8	44·1
La Paz	11,916	**4·5**	4·2	2·6	1·3	0·5	*0·3*	0·4	0·5	1·1	1·6	1·9	3·6	22·6
Sucre	9,350	**9·0**	5·5	3·6	1·3	0·1	*0·1*	0·2	0·3	1·5	1·9	2·5	4·1	30·2
South America, north of the Equator														
Bogotá	8,727	*2·3*	2·6	4·0	**5·7**	4·4	2·4	*2·0*	2·2	2·4	**6·3**	4·7	2·6	41·8
Maracaibo	26	0·2	*0·2*	0·3	0·5	**2·4**	1·6	1·4	*1·3*	3·3	**4·3**	2·5	0·4	18·0
La Guaira	coast	0·5	*0·2*	0·8	0·2	0·6	0·9	1·0	1·1	1·2	**1·6**	1·6	1·5	11·1
Carácas	3,418	0·9	*0·4*	0·6	1·5	3·0	4·0	4·2	**4·4**	4·1	4·2	3·6	1·8	32·7
Bolivar	125	0·5	0·4	*0·2*	1·0	3·3	5·6	**6·6**	6·4	4·0	3·5	3·5	2·0	37·0
Georgetown	6	8·0	*4·5*	6·9	5·5	11·4	**11·9**	10·0	6·9	3·2	*3·0*	6·1	**11·3**	88·7
Cayenne	20	14·6	10·7	12·2	14·9	**22·5**	13·2	6·6	2·0	*0·7*	1·3	3·7	8·2	110·6
Brazil. Uruguay. Paraguay														
Belém	42	12·5	14·1	**14·1**	12·6	10·2	6·7	5·9	4·4	3·5	3·3	*2·6*	6·1	96·0
Santarem	20	6·2	**12·0**	10·6	10·9	10·3	6·2	3·0	1·9	1·5	*1·1*	1·5	5·0	69·6
Manáos	144	10·3	9·8	10·8	**10·9**	7·9	4·4	2·7	*1·5*	2·4	4·7	6·1	8·9	78·7
Iquitos	328	10·2	*9·8*	**12·2**	6·5	10·0	7·4	6·6	*4·6*	8·7	7·2	8·4	**11·5**	103·1
Trinidad (east Bolivia)	774	6·9	5·3	5·4	2·5	2·2	1·3	1·0	*0·6*	3·1	7·6	9·5	**9·7**	54·2
Fortaleza (Ceará)	85	4·4	12·2	13·3	**13·5**	9·3	5·1	2·3	1·1	0·9	*0·2*	0·9	1·4	64·2
Quixeramobim	658	3·2	4·3	**7·5**	6·9	4·5	2·0	0·9	0·4	0·1	*0·1*	0·3	1·0	31·2
Recife (Pernambuco)	97	2·1	3·3	6·3	8·7	10·5	**10·9**	10·0	6·0	2·5	1·0	*1·0*	1·1	63·4
Sta. Anna	1,053	3·0	1·6	**5·8**	0·4	0·2	0·3	*0*	0	0·5	1·5	0·4	0·9	14·6
Bahia	154	*2·6*	5·3	6·1	**11·2**	10·8	9·4	7·2	4·8	3·3	4·0	4·5	5·6	74·8
Cuyabá	541	8·7	7·7	**8·9**	4·1	1·8	0·5	*0·4*	1·2	1·9	4·7	6·4	8·6	54·9
Ouro Preto	3,750	**16·6**	15·0	10·8	4·1	1·8	0·9	*0·9*	1·6	3·3	5·0	9·3	10·2	79·5
Ribeirão Preto	1,824	**11·0**	7·9	6·1	3·1	1·4	2·0	*0·6*	1·2	2·2	4·4	6·8	8·5	55·4

PRECIPITATION (inches) (*continued*)

Brazil. Uruguay. Paraguay (continued)

	Alt. feet	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Rio de Janeiro	201	5·0	4·5	5·5	4·2	3·3	2·3	*1·8*	1·9	2·6	3·4	4·1	**5·5**	44·2
Santos	10	11·0	9·8	**12·3**	7·3	6·1	5·7	4·3	*4·1*	5·7	6·4	7·7	7·8	88·1
São Paulo	2,425	**8·8**	7·5	5·8	2·5	2·5	2·0	*1·1*	2·0	3·0	4·4	5·4	7·1	52·1
Rio Grande	56	3·5	**5·7**	3·5	3·0	3·2	4·5	5·2	3·6	4·8	3·3	3·4	2·9	46·5
Asunción	456	5·5	5·1	4·3	5·2	4·6	2·7	2·2	*1·5*	3·1	5·5	5·9	**6·2**	51·8
Monte Video	72	2·9	2·6	3·9	**3·9**	3·3	3·2	2·9	3·1	3·0	*2·6*	2·9	3·1	37·4

The Argentine Republic

	Alt. feet	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Salta	3,865	**6·7**	6·2	3·9	1·2	0·4	0·1	*0*	0·2	0·4	1·2	2·3	5·4	28·4
Corrientes	177	4·1	4·7	**5·9**	5·7	3·9	1·8	2·0	*1·5*	2·8	5·0	5·3	5·7	48·4
Santiago	623	3·8	3·5	3·1	1·7	0·4	0·3	*0·3*	0·3	0·5	1·0	2·4	**4·0**	21·4
La Rioja	1,673	2·6	**2·7**	2·2	0·8	0·5	0·2	*0·1*	0·2	0·2	0·8	1·4	1·7	13·3
Concordia	80	4·3	*2·4*	**4·9**	3·6	3·0	*2·6*	2·9	3·2	3·7	3·4	3·1	4·8	41·9
Cordobá	1,388	3·9	4·2	3·5	2·2	1·4	0·4	*0·4*	0·5	1·1	2·4	3·4	**4·4**	27·4
Paraná	210	3·1	3·1	3·9	**4·9**	2·6	1·2	*1·2*	1·6	2·4	2·8	3·7	4·5	35·0
San Juan	2,178	**0·8**	0·7	0·4	0·1	*0*	0	0·3	0·1	0·1	0·2	0·2	0·4	3·5
Mendoza	2,625	0·9	**1·2**	1·1	0·5	0·4	0·3	*0·2*	0·3	0·5	0·7	0·7	0·7	7·5
Rosario	98	4·2	3·1	4·2	3·8	2·2	1·3	*1·2*	1·7	2·9	3·6	**4·3**	4·1	36·7
Buenos Aires	89	3·1	2·8	**4·3**	3·5	3·0	2·4	*2·2*	2·4	3·1	3·4	3·3	3·9	37·4
Azul	443	2·7	3·4	**3·5**	3·2	2·2	1·6	1·6	*1·4*	2·6	3·4	3·1	3·1	31·8
Bahia Blanca	95	1·9	**2·5**	2·3	2·2	1·4	*0·6*	1·0	0·6	1·7	2·8	1·9	2·2	21·1
Santa Cruz	39	0·6	0·3	0·4	0·6	0·4	0·5	0·4	0·6	0·3	*0·3*	0·4	**0·7**	5·4
Punta Arenas	92	1·4	1·3	1·2	1·5	**1·6**	1·5	1·1	1·1	0·9	0·8	*0·7*	1·5	14·6
Ushuaia	26	1·3	1·5	1·0	1·2	1·3	1·3	1·3	*0·8*	1·1	1·5	**1·9**	1·5	15·7

Mexico. Central America. The West Indies

	Alt. feet	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*
Chichuahua	4,669	0·2	0·4	0·3	*0·2*	0·2	1·7	3·6	**3·7**	3·3	0·9	0·5	0·4	15·2
Mazatlan	256	0·3	0·3	0·2	*0*	0	1·4	5·1	7·1	**10·3**	3·3	0·7	2·5	31·2
Manzanillo	26	0·2	0·1	*0*	0	0·2	3·9	5·5	6·6	**16·1**	5·5	0·7	2·7	41·5
Mexico City	7,487	*0·2*	0·3	0·5	0·7	1·9	4·1	**4·5**	4·3	4·1	1·6	0·5	0·3	22·8
Vera Cruz	52	1·0	0·6	*0·5*	0·6	1·8	11·4	**13·0**	10·7	12·0	5·7	3·1	1·0	60·2
Belize	17	6·1	2·3	*1·6*	2·4	4·6	8·5	6·2	6·2	8·8	**13·5**	8·6	7·0	75·8
Guatemala	4,888	0·3	*0·2*	0·5	1·3	5·5	**11·7**	7·8	7·8	9·3	6·6	0·9	0·2	53·2
San José	3,760	0·4	*0·2*	1·0	1·7	8·0	9·5	5·8	5·9	**10·8**	12·1	6·2	0·9	62·5
Colon	36	3·4	*1·5*	1·5	4·1	12·6	13·9	**15·6**	15·2	*12·5*	15·5	**22·4**	11·6	129·8
Culebra	350	1·6	0·7	*0·6*	3·6	11·1	8·8	9·3	10·3	10·7	11·5	**12·3**	7·2	87·7
Balboa Heights	118	0·9	*0·7*	0·7	3·0	7·9	**8·2**	*7·3*	7·9	8·1	10·1	**10·6**	4·3	69·7
Havana	62	3·0	*1·5*	1·7	1·7	5·1	**5·6**	4·3	*4·3*	5·0	**7·0**	3·2	2·4	45·0
Kingston (Jamaica)	110	0·9	*0·6*	0·9	1·2	**4·0**	3·5	*1·5*	3·6	3·9	**7·1**	2·9	1·4	31·5
Port Antonio (Jamaica)	10	8·6	6·5	*4·7*	7·0	15·4	**16·9**	10·6	11·1	*10·8*	14·9	**17·2**	13·0	137·3
Fort de France (Martinique)	13	4·7	4·3	*2·9*	3·9	4·7	7·4	9·4	**10·3**	9·3	9·8	7·9	5·9	80·5
Bridgetown (Barbados)	181	3·2	2·1	1·9	*1·6*	2·5	4·3	5·0	7·2	**7·6**	7·6	6·6	4·1	53·7
Port of Spain (Trinidad)	72	2·7	*1·5*	1·8	1·9	3·5	7·7	8·8	**9·6**	7·4	6·7	7·1	4·8	63·5

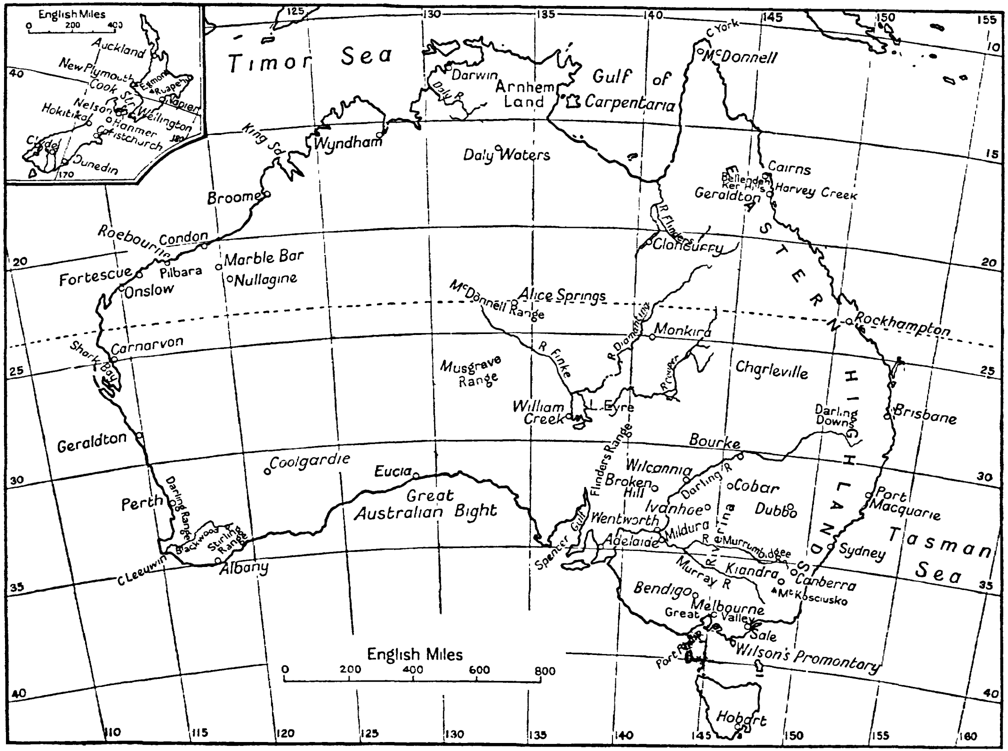


FIG. 175. Place-names mentioned in the text.

PART VII

AUSTRALIA, NEW ZEALAND

CHAPTER XLV

AUSTRALIA, GENERAL FEATURES

THE possibilities of the future development of Australia, which is the most arid of the continents, depend largely on the vital question of rainfall, so chief stress is laid on the circumstances to which the scantiness of the rainfall may be attributed.

Australia is in one of the driest belts of the earth, that of the sub-tropical high pressures and the trade winds which blow between them and the equator; excluding Tasmania it lies between latitudes 11° S. and 39° S., the tropic of Capricorn crossing it near the middle. It thus resembles north Africa, where the same latitudes of the north hemisphere include the Sahara, and also south Africa, where they enclose the arid section which includes the Kalahari and the coastal desert of South-west Africa. About 38 per cent. of the area of Australia has less than 10 inches of rain a year, only 9 per cent. more than 40 inches.

The interior of a continent naturally tends to have scanty rainfall owing to distance from the sea, the ultimate source of moisture. In this respect Australia has the advantages of being the smallest of the continents and of being insular. But, on the other hand, the land-mass is compact, the only large indentation in the coastline being the Gulf of Carpentaria, and the advantages conferred on Europe by her long coastline are conspicuously absent from Australia. There are no great lakes as in North America, only a few shallow salt-pans, usually dry when water is most needed in time of drought, and no great rivers provide rain in the interior by evaporation from their surface. The continent has its greatest length from east to west, as if to ensure that the maximum possible area should be subject to the most arid conditions.

Except in the east the relief is not favourable to heavy rainfall. The west half of the continent is a plateau between 600 and 2,000 feet above the sea, on which rise isolated highlands, such as the MacDonnell and Musgrave ranges which exceed

4,000 feet. The south-western rim of the plateau rises to 3,000 feet in the Darling scarp and Stirling range. All these heights cause a local increase in rainfall. The lowest tract is the region between the Gulf of Carpentaria and Spencer Gulf, most of it below 500 feet and the Lake Eyre district actually below the level of the sea, the lake itself 39 feet below. Much of Victoria and New South Wales in the basins of the Darling and Murray must be included in the lowlands, being less than 500 feet above the sea. The Eastern Highlands are the only extensive uplands; they start in the Cape York Peninsula, and for the most part do not greatly exceed 2,000 feet in Queensland, though small areas including the Atherton Plateau are much higher, the Bellenden Ker Hills reaching 5,000 feet to receive the heaviest rain of the continent. In New South Wales the general altitude is greater, exceeding 3,000 feet, and the Australian Alps in the south-east of the State attain 7,320 feet in Mount Kosciusko, the highest point in Australia and the only part which bears snow all the year. Considerable areas in eastern Victoria are above 3,000 feet. The larger rainfalls and lower temperatures are an attraction for settlers except in the south-east and especially in Tasmania which is too cold and wet.

A coastal plain, only slightly above sea-level, surrounds the continent. It is very narrow, 20 miles or less, in some places, but in others widens to 100 miles.

The influence of the relief is evident. The lowest tract, the Lake Eyre depression, is the most arid, with less than 5 inches of rain a year. The Eastern Highlands are the most rainy; in Queensland the SE. trade, normally a dry wind, gives very copious downpours on the windward slopes, and in New South Wales even anticyclonic winds rising over the range from seaward are rainy.

Oceanic Conditions

The north and east coasts are washed by the warm South Equatorial Current. Part of the current makes its way west, filling the shallow seas and straits north of Australia, which have the highest mean annual sea-surface temperature of the globe; part branches southward past Queensland and New South Wales as the warm East Australian Current. The west

coasts of south Africa and South America in the latitudes of Western Australia are remarkable for the cold water which in part is brought by the Antarctic Drift, in part wells up from below under the influence of the trade winds sweeping away the surface water. There is a tendency, most marked in summer, to the same conditions off the north-west of Australia, but the effect is far less pronounced, and the adjoining land has the hottest summers of the continent. The striking contrasts in temperature between the east and west coasts of the other southern continents are absent; indeed Perth is somewhat warmer than Sydney during most of the year. And as regards rainfall, which depends largely on the temperature of the sea, only near the tropic is the west coast of Australia desert, while hundreds of miles of the west coasts of the other continents are almost rainless. The cool Antarctic Drift keeps well to the south of Australia but surrounds Tasmania, leaving much warmer water in-shore along the Australian Bight.

CHAPTER XLVI

AUSTRALIA, TEMPERATURE

In summer (Fig. 176) the warmest region is the west where the sun is overhead and there is little cloud; a considerable area of western Australia is enclosed by the 90° isotherm in December. Almost all the continent north of the tropic has a mean temperature above 80°. The interior is warmer than the coasts, and the west coast warmer than the east. It is cooler towards the south, the isotherms having a general east–west direction, but tending to run parallel to the south coast, and curving northward as they approach both the west and the east coasts. The 65° line skirts the coast of Victoria.

The 90° isotherm continues to encircle the Pilbara plateau through February and March. The east is cooler than the west in all these months, and the mean temperature on the Queensland coast is as high as 80° only in January. April shows a marked fall; the 80° isotherm encloses the north and north-west, and the 55° isotherm is appearing over Victoria. July is the coolest month; the north-west coast is warmest with a mean about 75°, Victoria and the south of New South Wales

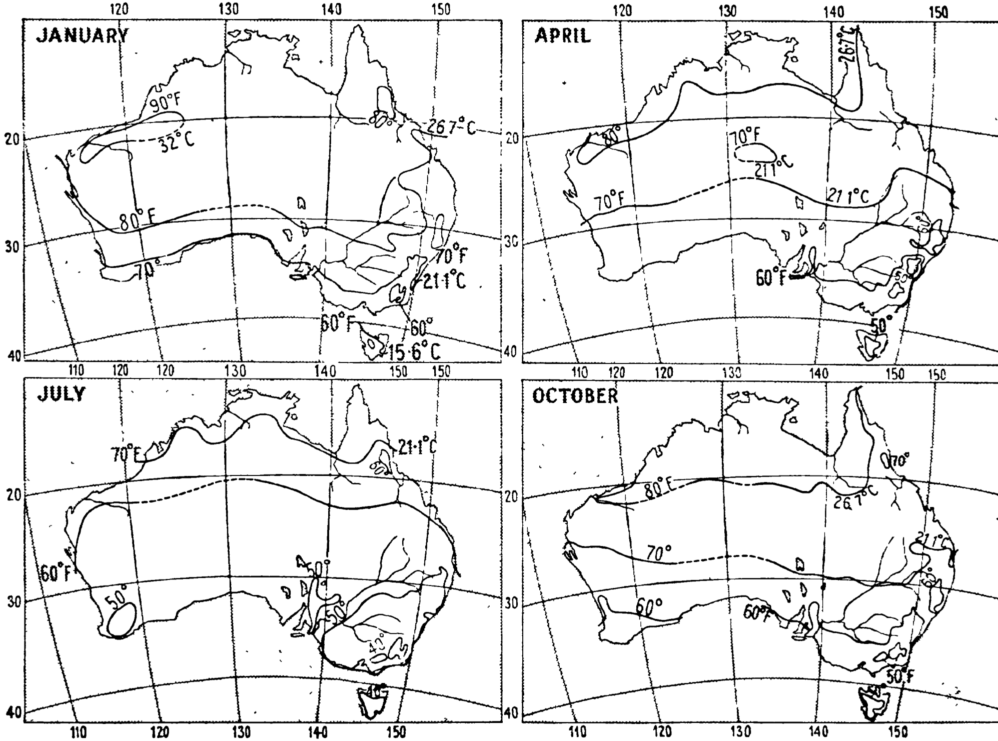


FIG. 176. Mean isotherms (based on *Climatological Atlas of Australia*, 1941).

coolest, below 50°; the west coast is warmer than the east as in summer.

Not only the highest means but also the highest midday readings are in the west and middle of the continent, a short distance inside the tropic as in Africa. According to official statistics the maximum shade temperature has exceeded 100° over an extensive area on 60 consecutive days. Marble Bar,

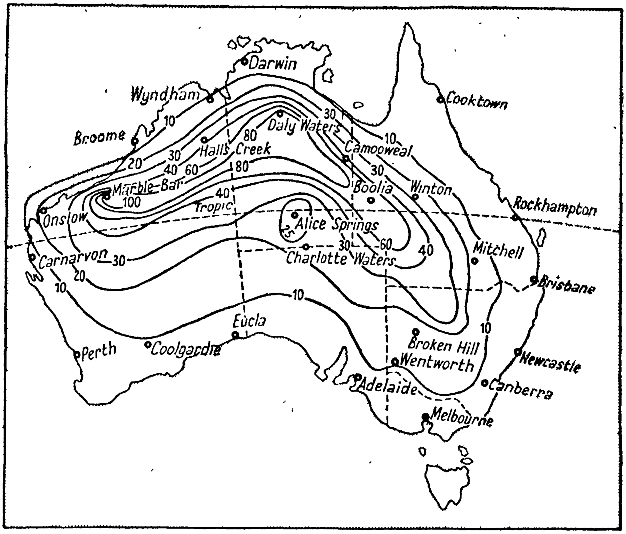


FIG. 177. Duration of a long heat-wave; the figures on the lines give the number of consecutive days with maximum shade temperature 100° or higher.

at an altitude of 600 feet, appears to have the most persistent heat, and here a maximum of 100° or over has been recorded on 161 consecutive days (Fig. 177); the absolute maximum temperature is 121°, the mean maximum for January 107°, the mean minimum for January 79°, figures almost as high as in the hottest parts of the Sahara. Even the coast of this region is intensely hot in summer; Roebourne, lat. 20° S., has recorded 117° in January, and the maximum has reached 90° or more daily for a spell of 220 days; the mean daily maximum is 100° or over in each of the 4 months November to February. Exceedingly high temperatures occur everywhere in the interior near the tropic, where the cloudless sky and dry air give free passage to the sun's rays (which are most powerful

in the southern summer when the earth is nearest to the sun). Stuart recorded 131°, and the sand was so hot that matches burst into flame when dropped on it. Alice Springs, almost on the tropic, 2,000 feet above the sea, reports 115° in most years. Intense heat is experienced as far south as the south coast; the thermometer at Bourke has touched 121°, at Adelaide 118°, at Melbourne 114°, at Sydney 114°; even the dryness of the air cannot render this extreme heat comfortable, and the smoke and heat from bush-fires sometimes intensify the stifling conditions. In the north of the continent, and on the Queensland coast north of the tropic, the heavy rain and thick clouds of the monsoon preclude such high temperatures; the warmest month at Darwin is November, mean 86°, and the highest temperature in most years does not much exceed 100°. At Cairns the mean in January, the warmest month, is 82°, and readings above 97° are unusual. But in winter these lower latitudes are much warmer than the rest of the continent; Darwin has monthly means above 80° in 9 months, the mean daily maximum exceeds 90° in all months except June, July, and August, and even in winter a reading below 60° is rare. At Cairns the July mean is 70° and the minimum is seldom below 50°, but despite the humid heat the littoral of Queensland has many white permanent settlers, and white labour, mostly British, works the plantations of tropical products though the mean ranges from 70° in July to 82° in January, and in 7 months the mean monthly wet-bulb temperature exceeds 70°.

Australia labours under many disabilities owing to her arid climate, but in one respect at any rate the dry air is an advantage, that it greatly tempers the summer heat by promoting rapid evaporation, and so lowering the physiological temperature, the heat actually felt by man. The wet-bulb thermometer is a better indication of the physiological conditions than the ordinary dry-bulb. The average wet-bulb readings in the western desert are about 20° lower than the dry-bulb, the mean for the summer months being only about 65°. At Melbourne the wet-bulb rarely exceeds 75° on the hottest days.

The relative humidity of the air is much lower in most of the continent in summer than in winter, although summer is

the rainy season. In the extreme north, however, it is lower in winter.

In winter the grass minimum may fall below freezing-point south of the tropic except on the west coast north of Perth, but it is rare on the east coast. Air frost has not been recorded at any of the State capitals except Melbourne and Hobart, though with the clear dry air the nights feel cold after the heat of the day. The coast between Rockhampton and Sydney is liable to cold katabatic winds from the adjacent mountains

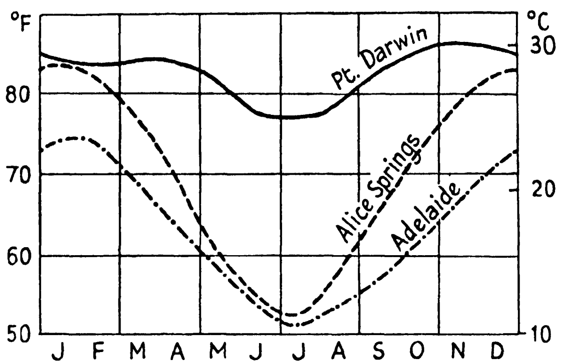


FIG. 178. Mean temperature.

in the night and early morning (and also, mostly in spring, to strong, very hot and at times dusty, winds from the far interior). Even in summer the nights are cool in the desert, and in most winters the thermometer falls to 25° at Alice Springs. But the winters in the interior are pleasant, and travellers naturally choose that season for journeys if possible, since the strong dry SE. wind makes even the hottest hours of the day bearable; water-bottles left on the ground outside all night may be frozen. On the south coast, though the mean temperature is lower, the nights are less cold thanks to the influence of the sea; at Adelaide the thermometer has fallen to freezing-point, but not below it, at Melbourne to 27°. Kiandra, 4,640 feet above the sea, in the Australian Alps, has recorded −8°.

Range of temperature depends as much on distance from the sea as on latitude. The mean annual range at Darwin is only 9°, the town being on the coast and in a low latitude, but at Adelaide it is 22°, and at Alice Springs 30° (Fig. 178). The

daily range is considerable in the dry season, largest in the arid interior:

MEAN TEMPERATURE

	Alt. feet	January Daily max.	January Daily min.	January Range	July Daily max.	July Daily min.	July Range	Absolute extremes
Darwin	97	90	77	13	87	68	19	105, 56
Alice Springs	1,901	97	70	27	67	39	28	115,[2] 27[2]
Perth	197	85[1]	63[1]	22	63	48	15	112, 34
Adelaide	140	86	61	25	59	45	14	118, 32
Melbourne	114	78	57	21	56	42	14	114, 27
Canberra	1,906	83	56	27	52	33	19	107, 18
Sydney	138	78	65	13	60	46	14	114, 36
Brisbane	134	85	69	16	69	49	20	110, 36

[1] February. [2] Mean annual extremes.

Comparing Australia with Europe in respect of temperature, we find that Melbourne resembles Oporto fairly closely. Perth, which is representative of the 'Mediterranean' climate region of Australia, has summers not unlike those of the French Riviera, but much warmer winters. Hobart is similar to Penzance.

The hot winds and cold winds, an important feature of the south and east of Australia, are described on p. 552.

CHAPTER XLVII

AUSTRALIA, PRESSURE AND WINDS

(Mean wind directions are given on p. 540.)

THE central feature in the meteorology of Australia is the high-pressure ridge, part of the sub-tropical high pressures of the south hemisphere, which appears clearly in the mean isobars for every month of the year. Its significance can be best appreciated from the point of view of the daily weather. The system shown by the mean isobars represents an almost constant procession of anticyclones (about 1 a week), moving from west to east at an average speed of about 17 miles an hour. Many of them enter Australia as more or less circular systems, but their east–west axis lengthens as they advance, till they may cover half the continent; a corresponding widening is seen in the mean isobars of the high-pressure area. An anticyclone is a system of subsiding air, which becomes warmer and drier with the result that there can be little cloud and rain, so that a country usually under anticyclonic conditions must have an arid climate. The winds blow outwards, and are deflected

to the left like other free movements in the south hemisphere of the rotating earth, to appear as SE. winds (trade-wind) on the equatorward side, with the usual trade-wind characteristic of dryness, caused both by their origin and by the fact that as they reach warmer latitudes their vapour-capacity is increased. On the poleward side the winds are north-westerly, and they also are dry as long as they are within the anticyclonic influence, but rainy in the cyclonic belt of the Roaring Forties.

Between each pair of anticyclones some arrangement of

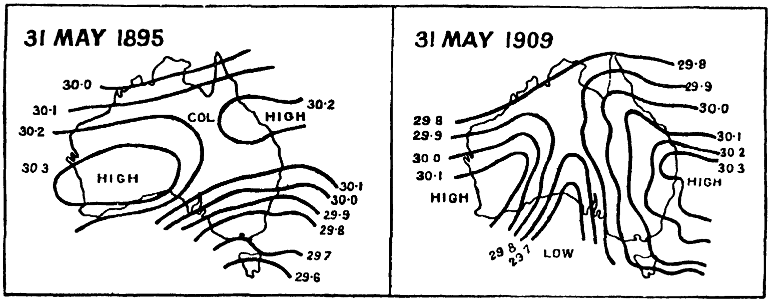


FIG. 179. Synoptic charts, col, trough.

lower pressure must intervene, just as higher pressures separate the successive depressions of the westerlies. A fully developed depression, however, is rare between the anticyclones of Australia. The lower pressures are usually merely in the form of a 'col'; a continuous ridge of high pressure persists, with separate anticyclones forming isolated 'summits' of still higher pressure (Fig. 179). Rain in any quantity is rare in such a col, and it is to be noted that, since the high-pressure ridge persists even in the col, the north and south of the continent are meteorologically separated; and the winds which originate in the high pressures in the middle of the land-mass can contain little moisture. But sometimes the ridge is completely broken down between two anticyclones, and a pronounced depression connects the low pressures on the north and the south. The word 'trough' may be applied to this formation, and the difference between it and the col, both as definite pressure-formations and as controls of the rainfall of much of the continent, is fundamental. The col may be compared to the mountain feature of that name, a saddle in a ridge between

the massifs on each side, while a trough is a valley cutting through the ridge and so effecting a complete separation of the massifs. The col is in one sense an anticyclonic formation preventing any passage of air from north to south through the baric ridge. But, like a valley which gives passage to a river from one side of a ridge to the other, a trough allows air-currents to sweep right across the continent, and it is in those circumstances that the interior of Australia, a region of scant precipitation, sometimes gets good rains falling in front of the

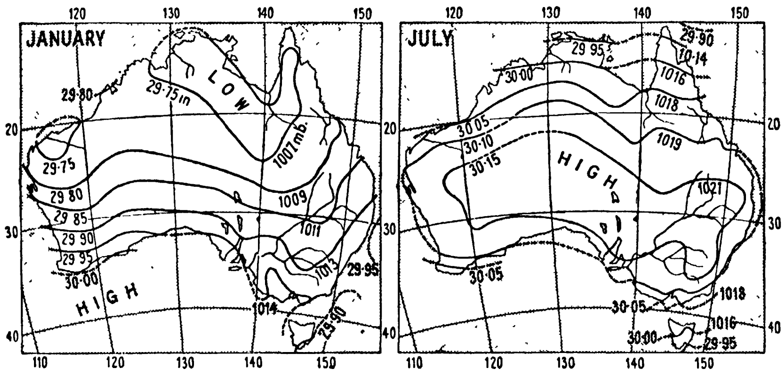


FIG. 180. Mean isobars (*Climatological Atlas of Australia*, 1941).

trough. A closed depression may develop in the trough in winter, and travel east over the south of Queensland into the Tasman Sea, giving a long spell of stormy weather.

The high-pressure belt enclosing the paths of the procession of anticyclones migrates seasonally, being farthest north, about 28° S., in winter; in July (Fig. 180) the 1,020 mb. (30·1 inch) isobar encloses most of the continent south of the tropic, the highest pressures being in the east. On the north pressure decreases steadily; the prevailing wind is the SE. trade which is rarely interrupted by disturbances, and this is the dry, fine-weather season in most of the continent north of the tropic, except the east coast where the on-shore winds give cloud and rain. South from the barometric ridge the gradient leads to the low pressures of the Roaring Forties, where depression follows depression at intervals of about a week throughout the year, with wild weather, strong winds and gales, overcast skies, and heavy rain; the prevailing winds are be-

tween NW. and W. generally, but very variable from day to day in direction and force. The variability results, in the south of Queensland and the north of New South Wales, mainly from the passage of anticyclones, but in the south of New South Wales, the south of Western Australia, and all along the south of the continent, from the depressions of the westerlies, which are the main control of the winter conditions in the 'Mediterranean' region of the south-west of Western Australia (Swanland) and the south of South Australia, and in all Victoria and Tasmania. Most centres pass from west to east far out to sea, causing the wild weather for which the Bight is famous, and only the extreme south of the continent derives some benefit from the rainy northern sectors. But often secondary V-shaped extensions, with the point towards the north, project even beyond the tropic between anticyclones of the high-pressure belt. When a depression makes its way farther north than usual, so that its centre passes over Victoria, the weather there is unusually boisterous and wet, and the south coast is swept by cold polar winds.

In summer pressure is lower everywhere. The high pressures are much diminished in width and intensity and, having swung south with the sun, are centred about 35° S., over and south of the south coast. The Antarctic depressions are kept well to the south and rarely give Australia much rain; Victoria, being farthest south, is most liable to be affected, but even here the rainfall is far less than in winter, but Tasmania is still within their influence. The rest of the south coast enjoys rainless and very sunny weather.

In the north pressure falls after September as the equatorial trough works south; the SE. trade weakens, the winds become variable, north-westerlies increasing in frequency, and the weather breaks with many thunderstorms, till by the end of December a fairly definite monsoonal indraught of moist equatorial air sets in from NW., with frequent steady rains, which persist with few breaks till March. This sultry season corresponds to the summer monsoon of south-east Asia, but the monsoonal winds are less strong and regular. The lowest pressures are in the hottest region of the north-west where a closed low-pressure system is centred (but the intertropical

WIND DIRECTIONS, MEAN PERCENTAGE FREQUENCIES

	N.	*NE.*	*E.*	*SE.*	*S.*	*SW.*	*W.*	*NW.*	*Calm*
Darwin									
Jan., 0900 . .	6	2	8	9	18	7	19	21	10
1500 . .	20	2	3	2	1	6	30	29	7
July, 0900 . .	1	1	20	52	21	1	0	0	4
1500 . .	30	3	7	14	15	1	6	17	7
Brisbane									
Jan., 0900 . .	9	7	16	21	21	6	5	11	4
1500 . .	13	44	26	10	1	1	3	2	0
July, 0900 . .	0	0	2	3	31	48	10	1	5
1500 . .	7	10	16	13	11	20	18	4	1
Sydney									
Jan., 0900 . .	7	14	16	8	22	8	14	11	0
1500 . .	2	18	40	17	17	2	4	0	0
July, 0900 . .	4	1	4	2	2	4	63	20	0
1500 . .	5	10	15	9	19	12	16	14	0
Wilson's Prom.									
Jan., 0900 . .	5	22	11	3	1	15	33	8	2
1500 . .	3	19	18	2	1	17	32	7	1
July, 0900 . .	20	19	6	4	4	9	11	26	1
1500 . .	14	19	6	5	4	10	17	22	3
C. Leeuwin									
Jan., 0900 . .	3	9	21	28	16	16	3	3	1
1500 . .	1	2	2	41	25	16	7	5	1
July, 0900 . .	13	13	3	4	12	17	25	13	0
1500 . .	8	8	5	7	10	20	24	18	0
NEW ZEALAND									
Auckland									
Jan., 0900 . .	7	21	8	4	10	31	10	8	1
1430 . .	11	17	9	9	11	25	15	1	2
July, 0900 . .	5	11	6	10	15	26	12	10	5
1430 . .	5	12	13	7	16	24	14	5	4
Dunedin									
Jan., 0900 . .	6	21	3	4	5	26	12	7	16
1500 . .	9	26	6	4	13	8	15	3	16
July, 0900 . .	5	16	1	2	5	28	12	4	27
1500 . .	11	17	2	3	2	8	21	6	30

convergence, the limit of the heavy tropical rains, does not usually advance south of the line King Sound to Cloncurry). On the west of this system the winds are SE., bringing continental tropical air, the drier after its long passage over the desert and incapable of giving rain; the heavy monsoonal rains extend down the west coast only to about 15° S., in contrast to the east where they cover almost the whole of the coast of Queensland. In April variables and south-easterlies begin to replace the monsoon, and by May the SE. trade blows steadily again over all the north of the continent day after day, with almost cloudless skies and dry air (except where the cool damp sea-breeze is strong). In Western and South Australia the SE. trade blows in summer with little interruption (save for the daily sea-breeze on the coasts) everywhere south of 22° S., bringing almost unbroken fine weather—the sunny, warm, rainless summer of the 'Mediterranean' climatic regions. On all the Queensland coast north of 25° S., also, the winds are SE., tending to E. north of the tropic, but they are on-shore and give much rain. The New South Wales coast has prevailing easterlies, but the winds are variable. Victoria and Tasmania are within the range of the westerlies, and have some rain and stormy weather, but far less than in winter.

The sea-breeze is strong in the warm hours round the coasts especially in summer; on the east coast it often attains gale force in the afternoon. The land-breeze at night is less prominent.

CHAPTER XLVIII

AUSTRALIA, RAINFALL

AUSTRALIA falls naturally into four rainfall provinces, the north, the south, the east, and the interior, determined directly by the distribution of atmospheric pressure. The north gets its rain in summer, when the high pressures have retreated far to the south, leaving the way open for the monsoon (Figs. 181 and 182). The south has most of its rain in winter, when the high-pressure belt is over the interior and the depressions of the westerlies reach the coast (Fig. 183). The interior of the continent is dry all the year, since neither the monsoon rains of summer nor the cyclonic rains of winter reach it in strength;

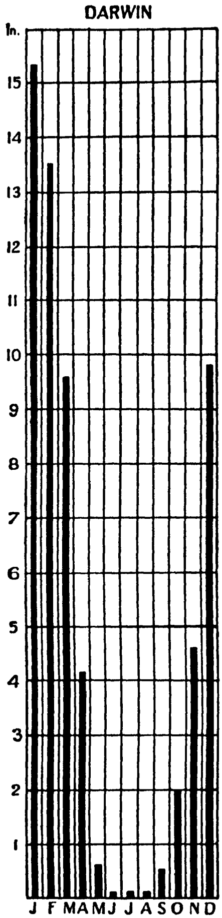


FIG. 181. Mean monthly precipitation.

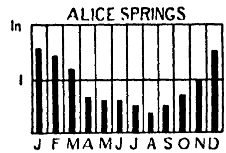


FIG. 182. Mean monthly precipitation.

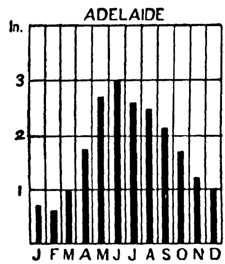


FIG. 183. Mean monthly precipitation.

this arid tract, with less than 10 inches of rain a year, is of vast extent, about 1,000,000 sq. m., 38 per cent. of the whole.

The percentages of the areas of the States with the specified precipitations are:

	Queensland	*N.S.W.*	*Victoria*	*South Australia*	*Western Australia*	*Northern Territory*	*Tasmania*
Less than 10 inches	13	20	0	83	58	25	0
10–20 „	34	41	38	14	29	42	1
20–40 „	41	33	52	3	11	21	43
More than 40 inches	11	6	10	0	2	12	56

South and Western Australia are the least favoured, 70 per cent. of their combined areas having less than 10 inches. Victoria and Tasmania are at the other extreme, much more than half having over 20 inches.

The rainfall is both scanty and very unreliable, the sky is almost cloudless and the sun glares down pitilessly on the bare

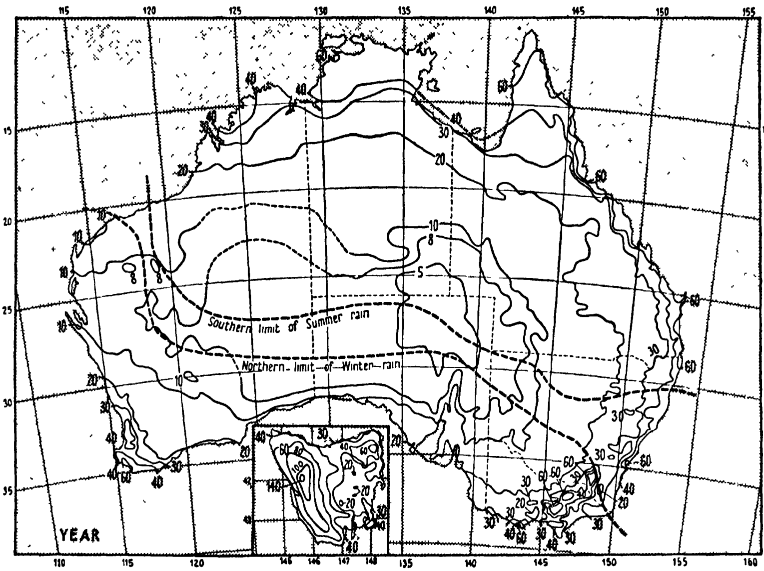


FIG. 184. Mean annual precipitation (based on *Climatological Atlas of Australia*, 1941).

rocks and sand-dunes; the air is very dry, especially in summer; occasionally the sky may be overcast and even thunderstorms may occur in the upper air, but no rain can reach the surface before it is evaporated in the hot dry air; the lightning flashes brightly, but little thunder is heard. The boundaries of the summer and winter rainfall provinces are shown in Fig. 184; the region between them is arid in the west and centre, and in the east gets some rain in all seasons (Fig. 185). The fourth rainfall province (Fig. 186) includes the east coast and the adjacent highlands and owes its existence to the relief; parts of it have the largest rainfall of the continent. The Queensland coast has E. and SE. winds, for the most part the trade, all the year; they bring maritime tropical air and in summer equatorial air (north of the tropic), and give copious rain. Tropical

cyclones in late summer add to the total. The coast of New South Wales has variable winds, being in the track of anticyclones which cross it in all seasons as they leave the continent; much of the rain may perhaps be described as anticyclonic, since it results from the ascent of E. winds from anticyclones over the Tasman Sea, saturated with moisture by their passage over the warm water. The west coast of Australia is not so favourably situated. Many anticyclones cross it as they do the east coast, but the southerly winds in front come from a cool sea to a warm land without sufficient height to cause much condensation; the easterlies in rear of anticyclones which have crossed the coast are even less effective since they blow from the land. In winter the rainy influence of the westerlies is appreciable to beyond Shark Bay, but the coast between Shark Bay and the tropic gets very little rain in any season, the arid tract with less than 10 inches of rain, which covers so much of the interior, reaching the coast.

The rainy area of Australia in the different seasons (Fig. 187) is aptly likened by the authors of *Climate and Weather of Australia* to a crescent, which covers the north-west, north, and east coasts in summer, the north-east, east, and south-east in April, the south-east, south, and south-west in July, and in October swings back to cover the east coast with its tips over the south and north. Thus it covers the east coast all the year, the north coast mainly in summer, the south coast mainly in winter, but the west never. The rainfall of Australia is essentially peripheral.

Regional features. Northern Territory has two well-marked seasons, the rainy and the dry. The dry season continues almost rainless till the end of September, when as the heat increases, the trade begins to fail. In the north thunderstorms begin early in October, and become more frequent and violent till, in November, the monsoon, blowing more and more steadily, brings hot moist equatorial air from the north-west; Darwin has 86 days in the year with thunder, most during the hot weather with weak and variable winds at the beginning and end of the rainy season. In December–March the sky is overcast with massive clouds and rain falls almost every day. The air is saturated with vapour, and the heat, though

less than just before the monsoon, is much more uncomfortable. The rains continue till the end of April, when SE. winds return with clear skies and cool nights. The rainfall is largest, over 60 inches, on the north coast round Darwin, and decreases southward, the 10-inch isohyet passing near Alice Springs.

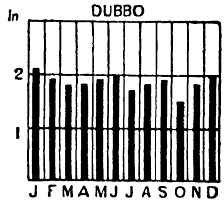


FIG. 185. Mean monthly precipitation.

The Queensland littoral is the rainiest part of Australia; the slopes of the Atherton plateau overlooking the coast have more than 140 inches a year, Harvey Creek 166 inches (over 22 inches in each of January, February, March, and April). Many stations have exceeded 20 inches in a day, and 36 inches was recorded at Crohamhurst on 2 February 1893; thunderstorms, however, are not frequent. Most of this coast has a dry season in the months June to October which have about 2 inches each. The dry season is more pronounced in the Cape York Peninsula; north of Cairns the annual mean exceeds 60 inches but the 5 months June to October are almost rainless, the régime having the monsoonal periodicity of Arnhem Land.

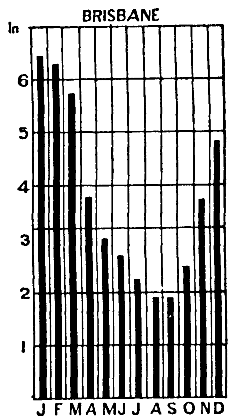


FIG. 186. Mean monthly precipitation.

The littoral of New South Wales also has good rain (though much less than Queensland), well distributed over the year, no months being deficient; in the neighbourhood of Sydney autumn has most.

All this east coast is liable to extremely heavy downpours; examples in the north are given above; the hills near Brisbane once had 105 inches in 12 days, and Sydney has had 9 inches in a day. At such times rivers have been known to rise in flood 80 feet above normal level.

In Victoria the precipitation exceeds 50 inches both on the highlands of the interior, and on the hills on both sides of Port Philip and on the south of the Great Valley. The east of the Great Valley itself has less than 25 inches. In Victoria, as in New South Wales, the rain is well distributed over the year, here with a winter maximum.

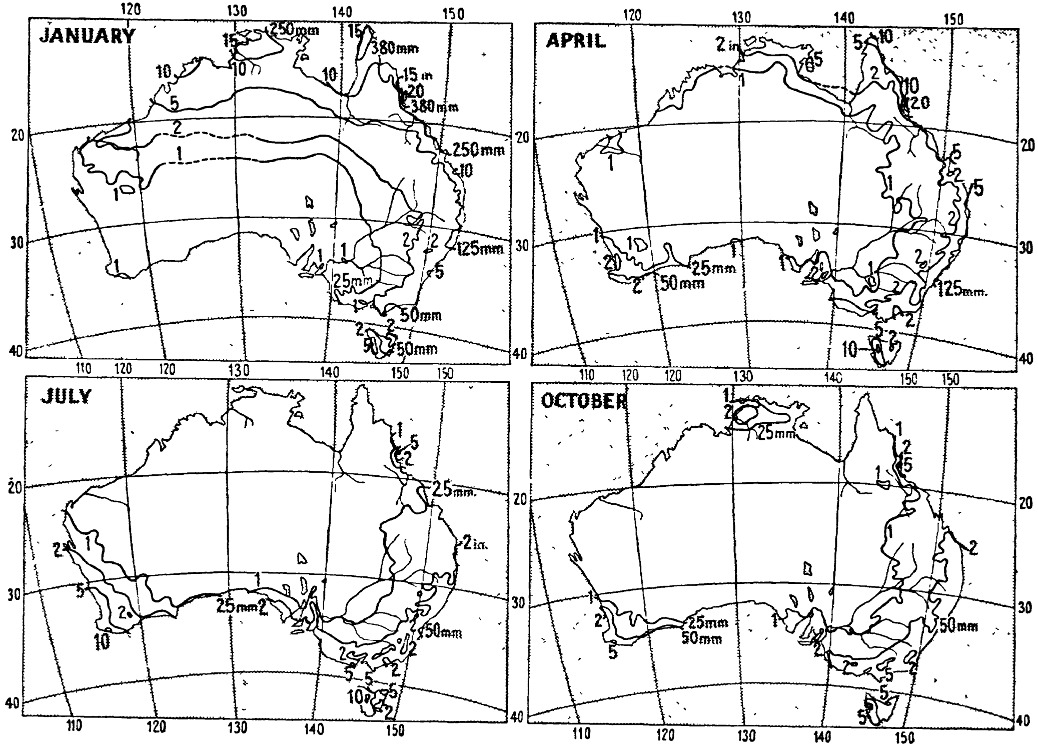


FIG. 187. Mean monthly precipitation (based on *Climatological Atlas of Australia*, 1941).

The 30-inch isohyet follows the 2,000-feet contour-line in much of New South Wales and Victoria. The Darling Downs have a pleasantly dry and cool climate, with from 20 to 30 inches of rain. The great sheep lands of the lower Darling have means of 10 to 20 inches uniformly distributed over the year. But evaporation is high, the evaporimeter at Broken Hill giving an annual mean of about 90 inches (January 12 inches, July 3 inches). The excessive evaporation in the hot and almost cloudless summer (121° F. has been recorded at Wilcannia) and the uncertainty of the rainfall are the great disadvantages of the region.

In South Australia the mountains have a good rainfall, and the 10-inch isohyet is thrust far north by the Flinders Range. The seaward end of the range near Adelaide has over 40 inches, Adelaide itself 21 inches a year, nearly all in winter. South Australia has a smaller proportion of its area with adequate rainfall than any other State, only 17 per cent. receiving more than 10 inches. The region round Lake Eyre, with less than 5 inches, is the driest part of the continent, and the lowest means, about 4 inches, are in the forbidding desert south of the lake.

The shores of the Bight are arid, the 10-inch isohyet coming down to the coast, but the south-west of Western Australia is much more favoured. The Darling Range and other elevated parts of the edge of the plateau face the cyclonic winds of winter, and a considerable area has more than 20 inches of rain, 40 in the neighbourhood of Cape Leeuwin; Perth has 35 inches. The rainy season is sharply defined and lasts from May till October; the rainiest months are June and July, each with over 6 inches round Perth. The rain is of the greater agricultural value as it falls in the cool season when evaporation is not excessive, and it has the further advantage of being fairly reliable, in contrast to the very serious variability from year to year in most of Australia (Fig. 188).

The Spencer Gulf region and the south-west of Western Australia form Australia's 'Mediterranean' climatic province. In the dry air and bright sunshine wheat flourishes excellently, and commands the highest prices in the world's markets. The olive and other characteristic trees of south Europe have been introduced with success.

Tasmania has a very large precipitation in the west, over 100 inches a year on the windward slopes (Lake Margaret 144 inches), the largest in Australia except on the Queensland littoral. But the east of the island, in the lee of the highlands, has less than 20 inches in places, the contrast between east and

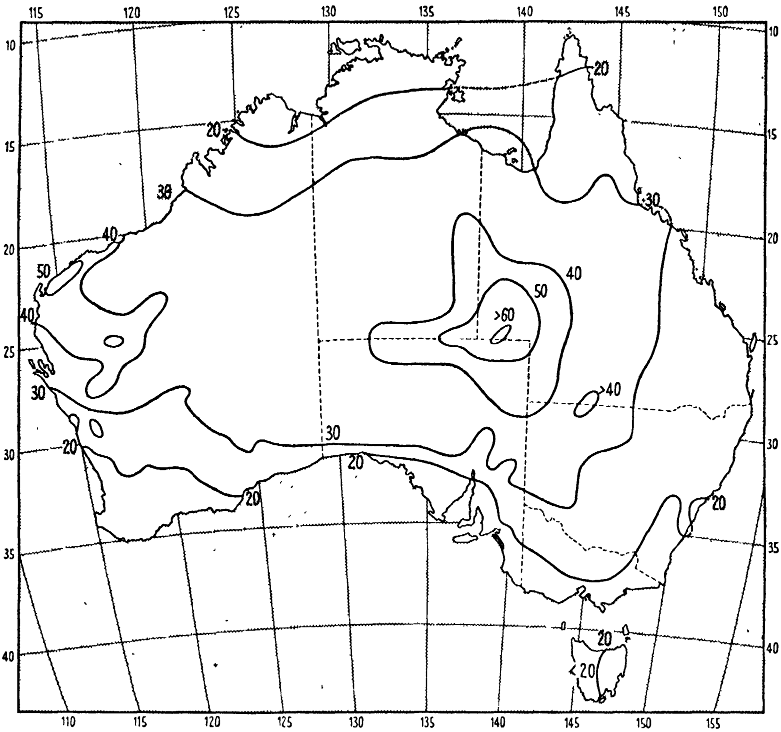


FIG. 188. Mean variability of annual precipitation, expressed as percentage of annual mean. (J. Gentilli.)

west being very sharp. Winter and spring have most rain and snow, but the differences between the seasons are small.

The unreliability of the rainfall and the danger of drought are most serious where the annual mean is between 10 and 30 inches, especially in western New South Wales and northern Victoria; settlers have established large farms in times of good or average rain, which fail in bad years, and general ruin results. But (Fig. 188) the variability is greatest in the almost uninhabited arid interior where the mean is less than 10 inches.

Even in normal years much of the rain in all the interior falls in short heavy thunderstorms, and with the vigorous evaporation a large proportion is wasted; but the scanty rain in the desert of South Australia tends to be more temperate. It is estimated that only 1·5 per cent. of the rain-water of the basin of the River Darling above Bourke flows past that town. Most of the rivers dry up, or become merely strings of water-holes, long before they can reach the sea or Lake Eyre. Lake Eyre itself is usually a great plain of salt, and only occasionally contains water. A station on the Darling once recorded no appreciable rainfall for 30 months. The Finke River in the middle of the continent may remain dry for several years and then be swollen by sudden rains to a breadth of 200 feet. Sometimes a single drought year is preceded and followed by years of plenty; or a series of years of deficiency may end with an especially dry year, and then the consequences are exceedingly disastrous. Nearly all droughts occur when barometric pressure is abnormally high, that is when anticyclones are large, and separated merely by shallow cols, not by deep troughs, so that a continuous high-pressure ridge fends off the Antarctic cyclones, and also prevents the monsoonal rains of the north of the continent from extending south. The summer rain fails more often than the winter. The rainfall records at Monkira, south-west Queensland, are suggestive; the annual mean is 9 inches, but one year had 29 inches, another only 2 inches, and 11 inches once fell in a single day. Roebourne on the coast of Western Australia has had 0·1 inch and also 42·0 inches in a year; Harvey Creek, Queensland, 80 inches and 255 inches (annual mean 166). The range at the state capitals is:

Annual Rainfall (inches)

	Mean	*Highest*	*Lowest*
Darwin	61	87	41
Perth	35	49	20
Adelaide	21	31	11
Melbourne	26	37	16
Sydney	47	83	21
Brisbane	45	88	16
Hobart	24	43	13

The rain is most reliable in the south, particularly in the Perth district, and in the north in Arnhem Land and the Cape York Peninsula.

Most of Australia never sees snow, and Sydney has had only one snowfall in the last 100 years. But it is frequent and often lies deep on the higher uplands of eastern New South Wales and Victoria, in Tasmania, and even in the extreme south of Queensland; on the Kosciusko plateau winter sports may be enjoyed down to 5,000 feet in most winters, and patches of snow persist through the summer in some years. The plateau edge behind the south-west of Western Australia is high enough to have a little snow in some winters.

Evaporation is hardly less important in determining the available water-supply than is the rainfall, with which it tends to vary inversely. In the arid interior the mean annual evaporation from a water-surface (tank) exceeds 100 inches (Alice Springs 97 inches). It is much less in the rainier regions, 66 inches at Perth, 39 at Melbourne, 40 at Sydney. It is far more in the hot than the cool months.

Dust-storms are frequent, as might be expected. During one in the neighbourhood of Adelaide in July 1935:

> High winds lifted the dust from the 'outback' country, enveloping the city and the extensive agricultural belt in a thick pall which was almost suffocating. The duststorm began yesterday morning and continued during the night; and this, the Government meteorologist says, is unprecedented. He makes the conservative estimate that 10 million tons of dust was deposited and probably 10 times as much remained in the upper air or was blown seaward. Shipping, trains, and road transport were held up everywhere, . . . ships were forced to remain in the port or anchor in the roadstead owing to the limited visibility. . . . In some parts of the north, where sandbanks stopped trains . . . people were forced to remain indoors the whole day (*The Times*).

CHAPTER XLIX

AUSTRALIA; TROPICAL CYCLONES, HOT WINDS AND COLD WINDS

Tropical Cyclones. Both the north-west and the north-east coasts are liable to destructive hurricanes of the type known in the West Indies (Fig. 189). Those of the north-west, willy-

willies locally, originate over the hot Timor Sea, and travel first south-west, the sequence of wind and weather on land indicating their proximity. The pearl-fishers at sea often suffer severe losses, but usually it is only while the storms recurve to the south-east that the coast feels their fury. They strike inland often between Condon and Fortescue, and work all the havoc for which tropical cyclones are noted. Thence they continue in the same direction over the interior of Western

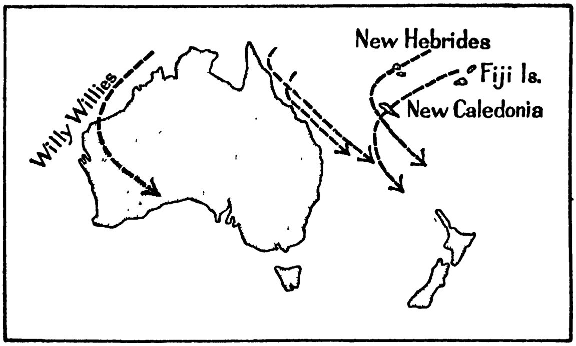


FIG. 189. Generalized tracks of tropical cyclones.

Australia towards the Great Australian Bight, but their violence is exhausted when they leave the sea, and they are rather welcomed in the interior for their heavy rains. If they reach the Southern Ocean they assume the form there of ordinary extra-tropical depressions. They occur during summer and autumn, on the average 2 a year. Very heavy downpours of rain may fall on the north-west coast during their passage, places with an annual mean of 12 inches having had more than 20 inches from a single storm. Neither South Africa nor South America have tropical cyclones in the corresponding localities, for the willy-willies in the north-west of Australia are a product of the very warm seas on the north and north-west of the continent, in the absence of a cool current off the west coast.

It is not surprising to find tropical cyclones off the north-east of Queensland, a region corresponding in position to the China Sea in the north hemisphere. They originate in the neighbourhood of the Fiji Islands (or farther east), where they do great damage. Some (average 4 a year) reach the Queensland coast, most between 15° and 20° S., few south of 25° S.,

and then recurve to the south-east on the usual parabolic course, but occasionally they continue westward to the Gulf of Carpentaria. In most years 2 or 3 work great havoc on the Queensland coast, and sometimes give excessive rain, but fortunately most recurve before the coast feels their full violence. Very few reach New South Wales.

The mean distribution over the year of tropical cyclones is:

MEAN PERCENTAGE FREQUENCY

	J.	*F.*	*M.*	*A.*	*M.*	*J.*	*J.*	*A.*	*S.*	*O.*	*N.*	*D.*
Willy-willies	30	19	23	9	0	0	1	0	1	1	2	14
Queensland cyclones	22	18	21	9	4	5	5	0	4	3	2	7

Whirlwinds or tornadoes (much less violent than those of the U.S.A.) are not infrequent in the south-east of Australia, most occurring in summer.

Hot Winds and Cold Winds. The south of Australia is liable to get very hot, dry, and dusty winds from the deserts of the interior. The temperature has been known to rise to 120° in the north of Victoria, and Melbourne has recorded a maximum over 100° on 6 consecutive days when the pressure-gradient was such as to cause a steady flow of air from the north.

In Victoria the hot winds are known as 'Brick Fielders', a name originally applied to the 'Southerly Bursters' in Sydney because of the dust they raised from the brickfields to the south of the city. When the gold fields were discovered in Victoria the miners hailing from Sydney gave the name to the dusty winds from the opposite quarter (*Australia Year Book*).

In the east of New South Wales hot winds are less prominent than strong cold winds from the south known as Southerly Bursters, a related phenomenon. A pair of anticyclones moving east are separated by a trough of low pressure in the form of an inverted V from a depression on the Southern Ocean, and when the trough extends, as it sometimes does, almost to the north of the continent, temperature falls sharply as the line of lowest pressure passes, cold polar air abruptly replacing the hot continental tropical air from the north. The latter constitutes the hot winds of South Australia and Victoria described above, the hotter owing to the nearness of the hot desert, but

on the littoral of New South Wales south of Port Macquarie the polar air is the more prominent, coming in after a day or two of hot sultry weather; temperature drops suddenly 20° or more. The wind usually approaches, and sometimes reaches, gale force. A striking roll of cumulus cloud about 50 miles long is often the vanguard of the burster, but it gives little or no rain. The passage of the trough (at a speed between 10 and 50 miles an hour) with its associated winds can be traced along the south of the continent, and up the east coast where it accelerates; its intensification in New South Wales is largely a result of the relief, the second of the pair of anticyclones being impeded by the eastern highlands; the southerly winds do not set in till the barometric gradient is steep enough to overcome the barrier, when they advance with some violence. The average number of bursters is 30 a year, most of them in spring and summer, none in winter.

CHAPTER L

NEW ZEALAND

THE main climatic features of the Dominion are readily under stood from a consideration of its position and relief. The islands lie within the variable westerlies of the south hemisphere all the year, and the prevailing winds blow strongly from NW., W., and SW.; Cook Strait in particular is noted for its strong and persistent NW. winds. The meteorological situation corresponds to that of the British Isles. But in summer, when the climatic belts have swung south, easterlies are frequent on the north peninsula of the North Island, and the rest of the North Island is then on the border of the westerlies, and enjoys much less windy and rainy weather than in winter.

The topography of New Zealand is such as to exert a strong influence on pressure-systems, fronts, and weather. The most effective features are: Cook Strait, only 15 miles wide west of Wellington but 100 miles in its western entries, with curved and indented shores; the scattered ranges and massifs of the North Island; and the continuous lofty highland extending from end to end of the South Island, with long reaches in the middle and south exceeding 7,000 feet and peaks over 10,000

feet; it separates the narrow littoral of Westland, backed by a high and steep escarpment, from the wider plains on the east. The usual cloud and precipitation of passing fronts are intensified or may even be absent according to the topography. The winds show a strong tendency to follow the coast-lines, particularly in Cook Strait and on the east of the islands.

Temperature

The temperature is equable for the latitude in these islands set in a vast ocean. The annual range is least on the west coast, 15° at Hokitika; Christchurch on the east coast has 18°. The winters are very mild, the summers cool. New Zealand is in the same latitudes as Italy, part of it indeed nearer the equator, but the mean summer temperature is 10° lower, and the extremes are very much less; at Auckland in the north 85° is not often exceeded.

The winters are slightly warmer in New Zealand than in Italy. Dunedin has similar temperatures to those of south-west Ireland, 400 miles nearer the pole; Auckland is comparable with Lisbon. The west coast is a little warmer than the east in winter thanks partly to the warmer sea-water brought by the East Australian Current (the east coast has cool Antarctic water), partly to the damper air and cloudier sky. In summer the east coast is the warmer, being to leeward of the heated interior; thus the interior and the east have slightly more extreme temperatures.

The daily range of temperature, like the annual, is small, as might be expected:

		January Mean daily			*July Mean daily*				
	Alt. feet	*max.*	*min.*	*range*	*max.*	*min.*	*range*	*Absolute extremes*	*Ground-frost, mean annual no. of days*
Auckland . .	160	73	59	14	57	46	11	90, 33	1
Wellington . .	415	68	55	13	51	41	10	88, 29	29
Christchurch . .	32	70	53	17	50	35	15	96, 21	21

Ground-frost is frequent everywhere, even on the low ground and on the coast (except in the north of the North Island), in winter and spring, and in most of New Zealand it is not unknown in summer; fruit and crops often suffer in late spring. The air temperature also falls below freezing-point on the low ground, sometimes in the North Island (but seldom on the coast), and more often in the South Island.

Sunshine

The Dominion has more sunshine than might be expected in a moist oceanic climate, the east of the islands almost as much as Italy, and considerably more than the British Isles. Nelson has the highest record with an annual mean of 2,510 hours, and most of New Zealand has over 2,000 hours:

Mean Sunshine (Hours)

	Month with most	*Month with least*	*Year*
Auckland	226, Jan.	120, June	2,033
Wellington	232 ,,	107 ,,	2,050
Nelson	264 ,,	156 ,,	2,510
Christchurch	211 ,,	103 ,,	1,967
Dunedin	189 ,,	91 ,,	1,711
Hokitika	209 ,,	113 ,,	1,918
[Rome, Italy	348, July	107, Dec.	2,362
Oxford, England	195, June	44, ,,	1,482]

The abundant bright sunshine is a very attractive feature of New Zealand. It is attributed by the Director of Meteorological Services of the Dominion to the effect of the bold relief in causing large-scale turbulence; this diminishes the development of the great layers of cloud due to stratification in the lower and middle troposphere which are only too common in the dull skies of many regions in the westerlies.

Precipitation

The rainfall (Fig. 190) resembles that of the British Isles both in amount and distribution. The relief is similar in the two regions, the land rising steeply from the west coast to a mountain barrier on the windward side. But in the South Island of New Zealand the mountains are higher and more continuous, rising to over 10,000 feet, and the area with excessive rainfall is larger. A wide strip, including the west coast and the mountains, has more than 100 inches of rain a year, much of the higher land 200, and parts probably 300, inches. East of the mountains precipitation decreases rapidly. Most of the east half of the South Island has less than 40 inches, part of eastern Otago less than 20, the lowest mean in the Dominion being 14 inches at Clyde. The Canterbury Plains have 20 to 30 inches.

In this drier region irrigation is available from the rivers of the Southern Alps.

Almost all the North Island has over 40 inches; no part has as much as the west of the South Island, none as little as the east, since the mountains are not nearly so continuous. Most of the higher mountains have more than 75 inches a year, Egmont more than 100 inches. Ruapehu is the only peak in the North Island with glaciers, and they are very small.

The rain is fairly evenly distributed over the year in the South Island, the cyclonic activity of the westerlies being almost as great in summer as in winter. The west half (Hokitika, p. 562) has little seasonal difference; October–January is the rainiest period, and October the rainiest month, February the least rainy. This régime is probably associated with the velocity of the wind, which is highest in spring and summer, for the rain is largely orographic. The drier part of the east half of the South Island also has its rain evenly distributed over the year, with a small summer maximum due to convection under the hot sunshine. But round Christchurch winter has a little more rain than summer.

The periodicity is strongest in the north of the North Island, which in summer is, to a certain extent, outside the stormy westerlies. Winter is the rainiest season, July the rainiest month; January, the least rainy, has about half as much rain as July. But there is no really dry season; the periodicity is not nearly so pronounced as in the Mediterranean region of Europe, with which the north of New Zealand has some affinity in climate. Another important difference is the comparatively cool summer, but in the neighbourhood of Auckland oranges, lemons, and grapes can be grown, as well as apples, pears, and the other fruits of north-west Europe which flourish in both the North and the South Islands.

An important relation appears between rainfall and temperature in the South Island under certain conditions. As everywhere in the westerlies, the weather is often controlled by a series of depressions travelling from south-west to north-east, south of the islands or over the south of the South Island. As they approach, northerly winds bring moist maritime air, tropical or modified polar, the ascent of which gives the

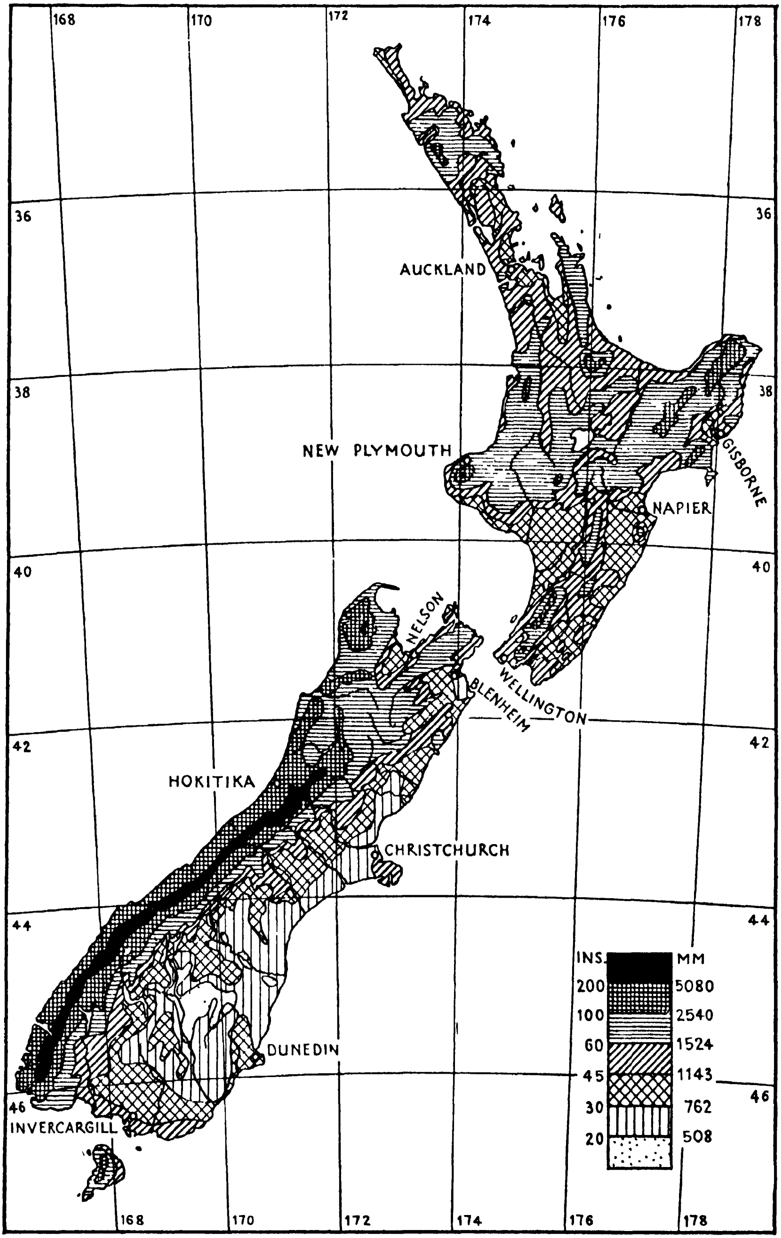


FIG. 190. Mean annual precipitation.

excessive orographic precipitation of the west coast and mountains; condensation liberates latent heat, and as the air descends to the plains on the east it has föhn qualities, being abnormally dry and warm but often strong and gusty (and the effect is intensified when westerly winds bring tropical air from the hot interior of Australia, which collects the more vapour on its sea-passage). The NW. winds can be hot and enervating on the Canterbury Plains; but as the depression passes on the wind veers to SW., bringing up polar air, cool and damp but refreshing after the previous heat.

The perennial rainfall combined with an equable temperature and abundant sunshine fosters the evergreen vegetation which is characteristic. New Zealand enjoys a great advantage over Australia in the amount, the duration, and the reliability, of its rain.

Snow. The highlands of the South Island, rising to over 10,000 feet, get very much snow which lies all the year above 7,000 feet and feeds many glaciers, the Franz Josef descending in a valley on the west (in the latitude of Marseilles) to 700 feet above the sea, and the Tasman flowing east with a length of 18 miles. The highlands in the middle of the North Island also have much snow which, however, does not lie long in most parts, but Ruapehu has a small snowfield and short glaciers. Snow is rare on the low ground in the North Island, and never lies on the coasts; but in the South Island the Canterbury Plains are liable to considerable falls, and on the east coast snow is not rare, but it does not often lie more than a day or two.

CLIMATIC MEANS

TEMPERATURE (°F.)

AUSTRALIA

	Alt. feet	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year	Range
Queensland															
Cairns	16	**82**	81	80	77	74	71	*70*	71	73	77	79	82	77	12
Brisbane	134	**77**	77	74	70	65	60	*59*	61	65	70	73	76	69	18
Cloncurry	633	87	86	83	79	71	66	*64*	69	75	82	86	**88**	78	24
Charleville	965	**83**	82	77	70	61	56	*54*	57	65	72	79	82	70	29
New South Wales															
Port Macquarie	43	71	**72**	69	65	60	56	*54*	56	59	63	67	70	63	18
Sydney	138	**72**	71	69	65	59	55	*53*	55	59	64	67	70	63	19
Bourke	92	**85**	83	77	69	60	54	*52*	56	63	71	77	82	69	33
Broken Hill	1,001	78	**78**	72	64	57	51	*50*	53	59	65	72	77	65	28
Canberra	1,906	**69**	69	65	56	49	43	*43*	45	50	56	62	67	56	26
Victoria, Tasmania															
Melbourne	114	67	**68**	65	59	54	50	*49*	51	54	58	61	65	59	19
Ballarat	1,430	64	**65**	60	55	49	45	*44*	46	49	53	57	61	54	21
Mildura	125	77	**77**	70	63	56	51	*49*	53	58	64	70	74	63	28
Hobart	177	62	**62**	59	55	51	47	*46*	48	51	54	57	60	54	16

TEMPERATURE (°F.) (*continued*)

	Alt. feet	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year	Range
							South Australia								
Adelaide	140	74	74	70	64	58	54	52	54	57	62	67	71	63	22
William Creek	249	83	83	77	68	59	54	53	56	63	71	77	81	69	30
							Western Australia								
Wyndham	23	88	87	87	86	81	77	76	79	84	88	89	89	84	13
Broome	62	85	85	85	83	76	71	70	73	77	81	85	86	80	16
Onslow	13	86	86	85	80	72	66	64	67	71	75	87	83	77	23
Geraldton	13	75	76	74	70	65	62	59	60	62	64	68	72	67	17
Perth	197	74	74	71	67	61	57	55	56	58	61	67	71	64	19
Eucla	16	70	71	69	66	61	56	54	56	59	63	66	69	63	17
Marble Bar	594	93	92	90	84	75	68	66	71	77	84	90	92	82	27
Coolgardie	1,388	77	75	71	65	57	52	51	53	58	63	71	76	64	26
							Northern Territory								
Darwin	98	84	83	84	84	82	79	77	79	83	85	86	85	83	9
Daly Waters	692	87	85	84	80	75	70	69	73	80	86	88	88	80	19
Alice Springs	1,916	83	82	77	68	60	54	53	58	65	73	79	82	70	30
							NEW ZEALAND								
Auckland	160	66	67	65	61	57	53	51	52	55	57	61	63	59	16
Napier	5	63	65	62	59	53	49	47	49	51	57	60	63	57	18
New Plymouth	60	63	63	61	59	54	51	49	49	52	55	57	61	57	14
Wellington	415	61	61	59	55	51	48	46	47	50	53	55	59	54	15
Christchurch	32	61	61	58	53	48	43	43	44	49	53	57	60	53	18
Dunedin	240	58	58	55	52	47	44	43	45	48	51	53	57	51	15
Hokitika	12	59	60	58	54	49	45	45	46	49	53	55	58	53	15

PRECIPITATION (inches)

AUSTRALIA

Queensland

	Alt. feet	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
McDonnell (Cape York)	190	17·2	15·6	12·0	5·9	1·4	0·6	0·5	0·4	0·2	0·6	2·9	8·3	65·9
Harvey Creek	coast	30·9	22·2	32·2	22·2	13·2	8·0	4·2	5·4	3·7	3·8	8·1	11·7	165·6
Brisbane	134	6·4	6·3	5·7	3·7	2·8	2·6	2·2	1·9	1·9	2·5	3·7	4·9	44·7
Cloncurry	633	4·6	4·3	2·4	0·7	0·4	0·4	0·3	0·2	0·3	0·5	1·3	3·2	18·6
Charleville	965	2·6	3·3	3·3	1·5	1·5	1·2	0·8	0·6	0·8	1·3	1·4	2·3	20·6

New South Wales

	Alt. feet	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Port Macquarie	43	5·9	7·5	6·5	5·9	5·6	4·6	4·5	3·8	3·9	3·2	4·1	5·9	61·5
Sydney	138	3·6	4·1	5·0	5·3	4·9	4·7	4·7	2·9	2·8	2·9	2·8	3·0	46·6
Bourke	92	2·0	1·9	1·6	1·4	1·1	1·0	0·9	0·9	1·0	1·1	1·3	1·1	15·2
Broken Hill	1,001	0·7	0·9	0·6	0·6	0·9	1·3	0·7	0·8	0·7	0·8	0·7	0·8	9·7
Wilcannia	266	0·9	0·9	0·9	0·6	1·0	1·0	0·6	0·7	0·7	0·8	0·7	0·8	9·9
Wentworth	125	0·8	0·9	0·8	0·7	1·3	1·3	0·9	1·1	1·2	1·1	0·9	0·9	11·8
Ivanhoe	499	0·9	1·0	1·0	0·7	1·0	1·2	0·9	0·9	0·9	0·9	0·9	1·0	11·5
Cobar	856	1·4	1·5	0·9	1·0	1·0	1·3	0·8	1·1	0·9	1·0	1·1	1·4	13·7
Canberra	1,906	2·1	1·8	1·9	2·1	1·6	1·7	1·6	2·0	1·5	2·3	1·8	1·7	22·1

Victoria, Tasmania

	Alt. feet	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Melbourne	114	1·9	1·8	2·2	2·3	2·1	2·1	1·9	1·9	2·3	2·6	2·3	2·3	25·7
Bendigo	823	1·3	1·2	1·5	1·5	2·1	2·6	2·0	2·2	2·1	2·0	1·4	1·2	21·1
Mildura	125	0·5	0·7	0·7	0·6	1·1	1·3	0·8	1·1	1·0	1·0	0·8	0·9	10·6
Hobart	177	1·8	1·5	1·8	1·9	1·8	2·2	2·1	1·9	2·1	2·3	2·4	2·1	24·0

PRECIPITATION (inches)

	Alt. feet	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
South Australia														
Adelaide	140	0·8	*0·7*	1·0	1·8	2·7	**3·0**	2·6	2·5	2·1	1·7	1·2	1·0	21·2
William Creek	249	0·5	0·4	**0·8**	0·4	0·4	0·7	0·3	*0·3*	0·4	0·3	0·4	0·3	5·4
Western Australia														
Wyndham	23	**7·3**	6·6	4·5	0·9	0·3	0·1	0·2	*0*	0·1	0·5	2·0	4·4	27·1
Broome	62	**6·0**	6·0	3·5	1·3	0·5	0·9	0·2	0·1	< 0·1	< *0·1*	0·7	3·8	23·0
Onslow	13	0·5	0·7	0·8	0·3	1·6	**1·8**	0·9	0·5	0	0	0	0·2	7·2
Geraldton	13	0·2	0·3	0·5	0·8	2·8	**4·9**	3·9	2·9	1·4	0·7	0·3	*0·2*	18·7
Perth	197	*0·3*	0·4	0·8	1·7	5·1	**7·1**	6·7	5·7	3·4	2·2	0·8	0·6	34·7
Albany	39	0·8	0·9	1·5	2·7	5·0	5·5	**5·6**	5·2	4·1	3·2	1·4	1·2	37·2
Eucla	16	0·7	0·5	0·9	**1·3**	1·2	1·1	0·9	0·9	0·8	0·7	0·7	*0·4*	10·2
Nullagine	1,266	**3·0**	2·4	2·2	0·8	0·7	0·9	0·5	0·3	< *0·1*	0·2	0·5	1·7	13·3
Coolgardie	1,388	*0·4*	0·9	0·9	0·9	**1·2**	1·2	0·8	0·9	0·7	0·6	0·6	0·7	10·1
Northern Territory														
Darwin	98	**15·3**	13·5	9·6	4·1	0·6	0·1	*0·1*	0·1	0·5	2·0	4·7	9·8	60·8
Daly Waters	692	6·1	**6·6**	4·6	1·1	0·2	0·3	< *0·1*	0·1	0·2	0·8	2·2	4·1	26·4
Alice Springs	1,916	**1·7**	1·5	1·2	0·7	0·6	0·6	0·4	*0·3*	0·4	0·7	1·0	1·5	10·8
NEW ZEALAND														
Auckland	160	*2·9*	3·4	2·9	3·6	4·6	5·0	**5·2**	4·2	3·7	3·6	3·3	2·9	45·3
Napier	5	2·9	3·0	2·9	3·0	3·5	3·4	**4·0**	3·3	2·2	*2·1*	2·4	2·3	35·1
Wellington	415	3·2	3·2	*3·2*	3·8	4·6	4·6	**5·4**	4·6	3·8	4·0	3·5	3·5	47·4
Hanmer	1,224	3·7	3·5	*3·2*	3·4	4·4	3·4	4·3	3·3	**4·5**	3·9	3·5	3·9	45·0
Christchurch	32	2·2	*1·7*	1·9	1·9	2·6	2·6	**2·7**	1·9	1·8	1·7	1·9	2·2	25·1
Dunedin	240	3·4	2·8	3·0	2·8	3·2	3·2	3·1	3·0	*2·7*	3·0	3·2	**3·5**	36·9
Hokitika	12	10·3	*7·5*	9·4	9·3	9·6	9·1	8·6	9·4	8·9	**11·5**	10·5	10·3	114·4

PART VIII

ANTARCTICA

Position and Relief (Fig. 191).

Antarctica is a large continent almost twice the size of Australia. Expeditions have had quarters at a few points on

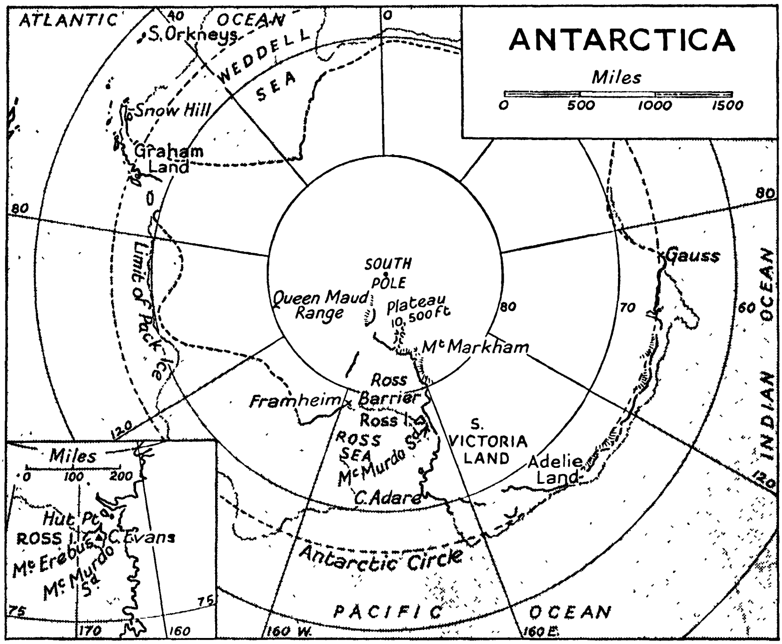


Fig. 191. Place-names mentioned in the text.

the coasts, and there are semi-permanent settlements in Graham Land; except for the very few polar journeys from the Ross Sea the far interior is untrodden by man, and little has been surveyed even from aircraft. It seems to be an unbroken mass of land, though the possibility remains that ice-covered channels of the sea divide it. The surface is a vast expanse of snow and ice, the few exposures of bare ground on the coasts and on steep mountain slopes being hardly appreciable climatically.

The continent lies round the south pole, but not symmetri-

cally. Towards the Atlantic, on the meridian of Greenwich, the coast is 20° of latitude distant from the pole, but in the opposite direction, towards Australia, only 5° in the south of the Ross Sea (which, however, is covered by the Ice Barrier). On the east, towards the Indian Ocean, the distance is about 23°, on the west, towards the Pacific, 17°. The dissymmetry is the greater owing to two large indentations, the Ross Sea penetrating to 85° S. and the Weddell Sea to 78° S.; the former is covered with pack-ice only in winter, but the Ice Barrier is high (its surface 170 feet above the sea), solid, and permanent south of about 79° S.; the Weddell Sea is heavily beset all the year. Graham Land is a prominent salient projecting as a narrow mountainous peninsula to 63° S. Despite its dissymmetry, however, Antarctica is much more a polar land than any of the lands in the north hemisphere.

The continent rises steeply from most of the coast to over 6,000 feet and then generally much less steeply. The conception of the interior formerly current, a dome covered with ice and snow centred on the pole, has been shaken by recent exploration. A range of mountains, rising to more than 12,000 feet about 200 miles south-east of the coast of the Weddell Sea (with the snowfield just inside the range estimated to rise to about 15,000 feet), has been discovered, and some evidence suggests a possible continuation to the coast of Queen Mary Land in east Antarctica. Another prominent range is the Queen Alexandra Range which rises on the west of the Ross Sea with peaks up to 15,000 feet. Graham Land is the tapering end of elevated land exceeding 6,000 feet at the root of the peninsula and 12,000 feet in 77° S., 87° W., which very possibly continues as a lofty range far to the south-east. The pole itself, at about 9,000 feet, seems to be in a wide depression between these ranges rather than on the top of a dome, but details cannot be guessed. Large differences of altitude and of slope must be numerous in such a large area, and there must be many gulfs and bays, the ice-covered seaward ends of valleys and lowlands, round the coasts. Meteorological research awaits knowledge of the topography which is a more fundamental control here than in most other lands; the vast snow-surface is a very efficient radiator, a cause of the intensely cold winters, and the chilled surface air descends any slope of

the smooth surface katabatically, to attain gale velocity in favourable topography.

The zone of heavy continuous pack-ice, almost or quite impenetrable by ships, which besets the land nearly everywhere to distances varying locally and seasonally but averaging 200 or 300 miles, may almost be regarded as part of the continent meteorologically; outside it the floes get rapidly more broken, but icebergs drift far north.

Long series of meteorological records are lacking even on the coasts, but many expeditions, on land and in ships drifting along the coasts, have brought back valuable records for the one or two years of their stay. The exhaustive examination and discussion of the data compensate to some extent for their scantiness. Special mention must be made of the work of Meinardus on the whole region, and of Sir G. C. Simpson on the results of the British Antarctic Expedition 1910–13.

Pressure and Winds

It has long been known that pressure decreases southward from the sub-tropical high pressures of the south hemisphere. On the almost continuous Southern Ocean, which surrounds the earth with fairly uniform temperatures along the parallels, the mean isobars are less irregular than in the corresponding latitudes of the north hemisphere, and it was formerly thought that the decrease of pressure continued to the pole, the low pressures being a result of the strong centrifugal force in the polar whirl of W. winds. Exploration, however, has shown that pressure begins to increase again at the coast of Antarctica; the dynamical effect of the circumpolar whirl is more than counterbalanced by the intense cold of the snow-covered continent, which is conducive to high atmospheric pressure. The mean pressure is lowest between 60° and 70° S., about 63° S. in the Atlantic and Indian Ocean sectors, 66° S. towards the Pacific (but about 61° S. in Drake Strait, the projection of Graham Land carrying the continental high pressures north), 70° S. off the Ross Sea; the low-pressure trough tends to follow the large indentations of the coast. A sign that the trough of lowest pressure has been passed as ships make their way to the far south is the change in the winds from westerly to easterly; the South Orkney Islands (61° S.) are just north of the lowest

pressures, and during her stay there in 1902–4 the *Scotia* found 71 per cent. of the winds westerly, only 2 per cent. easterly, but at Snow Hill, Graham Land (64° S.), S. and SSE. winds prevailed in the winter and spring of 1902–3. The *Gauss* station (66° S., 89·6° E.) had easterlies with little interruption in 1902–3. The Ross Sea provides longer records; the *Discovery* expedition at Hut Point had prevailing ENE. winds in 1903, and the British Antarctic Expedition at Cape Evans almost constant E., ESE., or SE. winds in 1911–13, these directions making 84 per cent. of the observations. At Framheim on the east of the Great Barrier Amundsen found E. winds in 1911, and SE. was the prevailing direction at Cape Evans also in the same year. The E. and SE. winds on the coasts of Antarctica are the natural circulation round the continental anticyclone. The westerlies are similar to those of the north hemisphere, but the pressure irregularities tend to be more intense, the winds stronger, and the seas and swell higher; gale follows gale, often with little interruption, in this wild tract of open ocean.

The anticyclone, though of great size, is shallow like other 'cold' anticyclones, and of no great intensity; Meinardus estimates the mean annual pressure in the central regions at not much more than 994 mb. (29·3 inches) and the depth about 5,500 feet. The mean pressure varies seasonally, being higher in summer than in winter and spring; the mean velocity of the wind has been highest in autumn and winter at most stations.

Above the anticyclone the poleward pressure-gradient from the sub-tropics, and the circumpolar whirl of W. winds, continue to the pole. These upper winds are indicated by the movement of the middle clouds (10,000–13,000 feet), by the drift of the smoke from Mount Erebus (13,000 feet), and in recent times by some pilot-balloon observations; these show, in the McMurdo Sound region, prevailing winds from between W. and N., the opposite of the surface directions (Fig. 192). The steep rise of Antarctica from the coast carries the surface above 6,000 feet not far inland, so that most of the interior projects above the anticyclone into the polar cyclone above. The anticyclone dominates only the outer ring, and the pressure seems to be little more than in the low-pressure trough on the ocean. Though the surface winds in it are predominantly

easterly they are by no means constant in direction or speed; the anticyclone is not a permanent unchanging system, and it seems likely that it is liable to be invaded and displaced by depressions from the ocean, which bring damp and warmer air into the continent, and give the precipitation, almost all of it snow, which is the chief source from which the snowfields are fed.

In addition to the anticyclonic winds katabatic air-move-

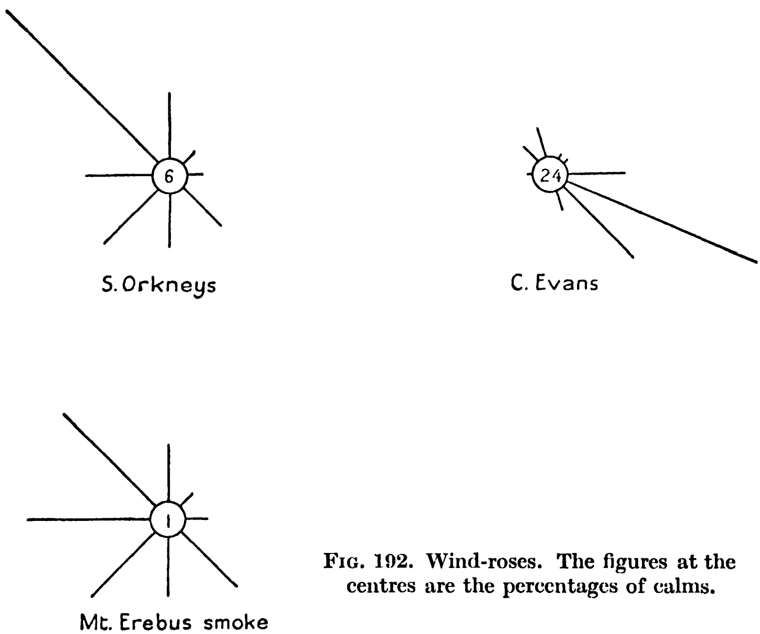


FIG. 192. Wind-roses. The figures at the centres are the percentages of calms.

ments are widespread on such snow-covered domes as Antarctica and Greenland contain, the very cold surface air descending the slopes and reaching great speeds where the slopes are long and steep. Possibly the blizzards of some regions are due to katabatic winds, and the extraordinarily violent S. winds which Mawson found to rage almost continuously in Adelie Land, the 'home of the blizzard', with a mean speed of almost 50 miles an hour, had the same cause, acting in specially favourable topography. The winds on the snowfields round the pole seem to be largely katabatic; Shackleton found SSE. to SSW. winds in the summer of 1908–9, Scott almost

constant (73 per cent.) S., SSE., and SSW. winds on his last journey in 1911, and Amundsen similar winds in the same summer.

Many features of the weather which have been reported from much of Antarctica seem to result from anticyclonic conditions —the clear sky (and hence very strong radiation of heat from the snow), dry air, scanty precipitation, frequent calms or light winds. But the calms often give way, very abruptly, to

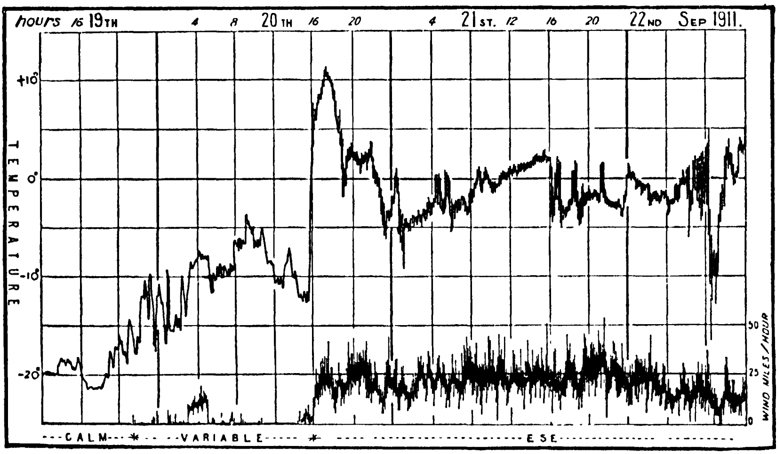


FIG. 193. Wind and temperature in a blizzard.

strong and very gusty winds exceeding even 70 miles an hour, which may drop again as suddenly as they rose. Boisterous weather, violent winds with driving snow, 'blizzards', have been a trial to all explorers. The essential features of the blizzard are the strong wind, generally from the south, and, equally important, the thick whirling snow that fills the air so that visibility is reduced to a few yards, and the traveller is bewildered and lost; how much of the snow is swept up from the ground, how much descends from the clouds, it is impossible to say, but probably most of it is new snow from above. The disturbance usually springs up very quickly, a calm changing within a few hours to a wind blowing in furious gusts of 30 to 50 miles an hour (Fig. 193), and the storm may last for a few hours or even a few days. In winter the temperature rises steeply when the storm begins, a rise of 32° having been recorded, but in summer it generally falls.

In 1911–12 blizzards were raging almost a quarter of the time at Cape Evans, but hardly any occurred at Framheim. Cape Adare had a remarkably high proportion of calms, the wind being less than 5 miles an hour for over 70 per cent. of the period of observation, and yet hurricanes (not, however, the blizzard type) of over 70 miles an hour occurred each month. Evidently the wind is controlled largely by the topography here and probably all round Antarctica. On the coasts such storms might well seem, on first consideration, to be associated with passing depressions of the westerlies, the south sectors of which may sweep the edge of Antarctica. But it is difficult to apply this explanation to the blizzards which were so prominent on the west of the Barrier, far from the open ocean. The examination of his own records at Cape Evans and those made simultaneously at Framheim and Cape Adare convinced Simpson that the disturbances, in the Ross Sea region at any rate, have no connexion with depressions of the westerlies, and are not circular cyclonic systems, but some form of pressure-waves or surges moving out from the interior. The steep and lofty plateau edge which bounds the Barrier on the west appeared to be the cause of the frequency of blizzards there, owing to the obstacle it presents to the E. winds. At any rate it would seem that the blizzards on the west of the Barrier, which were a large factor in the disaster to Scott's polar party, are a local feature, for Amundsen, whose route led across the Barrier much farther east, found comparatively light winds (Simpson, *Scott's Polar Journey and the Weather*).

At Framheim in 1911 42 per cent. of the observations were calms or very light winds of under 4 miles an hour, and only 2 per cent. over 30 miles an hour, but at Cape Evans (1911–12) only 22 per cent. were calms or light winds and 30 per cent. were of more than 30 miles an hour. The high percentage of calms shows dominant anticyclonic conditions at both stations; the records at Cape Evans show the frequency also of the opposite conditions, raging blizzards.

More than one theory of blizzards has been advanced. Simpson's theory, based on the Ross Sea region, assumes the existence on the surface of the calm layer of very cold air already referred to, a layer so stable that even strong winds in the higher atmosphere can override without disturbing it. But

when the air-movement aloft becomes still more vigorous turbulence gradually spreads downwards and in a short time the whole of the surface layer is mixed with the gale above. Thus the blizzard is merely the extension to the surface of a very strong wind in the higher atmosphere due to a temporary steepening of the barometric gradient. This theory goes far to explain the greater frequency of both calms and high winds than winds of moderate strength. It also explains the sudden rise in temperature at the beginning of a winter blizzard, the very cold surface air being replaced by the warmer general currents. Later examination of the 1911–12 results, and additional observations, seemed to indicate that Simpson's pressure-waves are not required to explain the weather sequences observed; the pressure and weather changes in the Ross Sea area could be explained better as being controlled by the well-known depressions of the westerlies to the north; strong southerly winds and blizzards were polar winds intensified by the katabatic effect of the topography. Recent investigations, however, tend to prove the reality of pressure-waves travelling from east to west, whatever their origin may be.

Temperature

It is not surprising that the Antarctic winters are very cold. More characteristic are the cold summers, so cold that land animals (except birds and insects) and flowering plants are almost absent as well as permanent human settlements. The astronomical facts suggest warmer conditions, for in summer the earth makes its nearest approach to the sun, and on 21 December more insolation is received in the 24 hours above the south pole than in any other latitude on any day of the year. But the air temperature is controlled much more by the surface of the ground with which the air is in contact than by the direct passage of the rays of the sun. The long oblique course through the atmosphere weakens the insolation so much that the sun even at its greatest altitude is not powerful enough to melt the snow, the temperature of which, and consequently of the air also, remains well below freezing-point. The mean air temperature of the warmest month is probably below 32° everywhere inside the Antarctic circle except round the Ross Sea where the 32° isotherm seems to swing remarkably far south,

to about lat. 75° S. The coasts of the boisterous Southern Ocean have means in December and January about 30° in east Antarctica, 24° in west Antarctica which is in higher latitudes; Cape Evans has 24°, the Ice Barrier 15° (estimated). Round McMurdo Sound (see table below) the mean daily maxi-

MEAN MONTHLY TEMPERATURES (°F.)

	McMurdo Sound, 5 years (C. Evans and Hut Pt. records combined)	*Framheim, 1911–12*	*C. Adare (computed by Simpson)*	*'Gauss', lat. 65° S., 1902*	*Graham Land, Snow Hill, lat. 64·5° S., 1902–3*	*Graham Land, Barry Is., alt. 50 ft. 68·1° S., 67·1° W. 1936–7*	*S. Orkneys, 1903–34*
Jan.	24	15	(32)	31	30	35	32
Feb.	16	(4)	(27)	(26)	24	31	32
Mar.	4	−7	19	17	13	30	31
Apr.	−9	−18	9	4	7	25	26
May	−11	−32	−2	7	0	8	19
June	−12	−30	−15	1	−4	0	13
July	−15	−34	−12	−1	−6	6	12
Aug.	−15	−49	−14	−7	−3	6	14
Sept.	−12	−35	−7	0	3	20	20
Oct.	−2	−12	−1	9	14	28	24
Nov.	14	4	19	20	17	33	28
Dec.	25	20	29	30	28	35	31
Year	1	−14	7	11	9	22	23

mum is well below 32° in every month, but probably the temperature rises above 32° once or twice in December and January in most years; but it may also sink almost to zero.

For the polar plateau we have the records made in December 1911 and January 1912 by Amundsen and Scott. The mean temperature in December was −8·6, in January −18·7; the lowest record −19·3 in December and −29·7 in January; the highest maximum, 5·5 in December and −3·2 in January. From 22 December till 6 February on the plateau Scott did not once record a reading above zero. The steep fall from December to January shows how rapidly temperature responds to the changing altitude of the sun, a result of the good insulation of the dry snow.

In summer the sun is above the horizon all the 24 hours for at least 1 day everywhere in Antarctica. At the pole its

altitude is almost constant throughout the 24 hours of each day during the 6 months that it is above the horizon, though it rises slightly higher day by day to a maximum altitude of 23·5° on 21 December, and presumably the mean diurnal range of temperature is very small; in the 4 days 16–20 January when Scott was within 30 miles of the pole, the highest reading was −19·1, the lowest −26·7. The difference between the midday and midnight altitudes of the sun increases with decreasing latitude; at 70° S. the altitude is 43·5° at midday, only 3·5°

TEMPERATURE (°F.) AT MCMURDO SOUND (CAPE EVANS, 2 YEARS, AND HUT POINT, 2 YEARS, RECORDS COMBINED)

	Mean			
	Daily maximum	*Daily minimum*	*Absolute Maximum*	*Absolute Minimum*
January	29	17	40	4
February	20	9	33	−9
March	9	−2	27	−20
April	−2	−15	19	−42
May	−5	−21	17	−51
June	−5	−22	21	−47
July	−6	−24	16	−54
August	−7	−24	18	−53
September	−5	−23	16	−59
October	2	−12	24	−43
November	19	7	34	−7
December	29	18	42	4

at midnight, on 21 December, and the consequent diurnal range of temperature is remarkably large; on the Barrier Scott's party recorded a mean range of 20° during a spell of 6 calm clear days in November, and the mean for November, December, and January was 11°. But at McMurdo Sound the range was much less, the highest, that for January, being only 5°. The high range on the Barrier is a result of the insulation by the loose snow; the changing intensity of insolation as the sun rises and sinks is reflected rapidly in the air temperature. The range is considerably larger in the early summer when the snow is dry and loose than at the end of the season. Partly for the same reason the warmest month is December and not January, the decreasing altitude of the sun after the solstice having an almost immediate effect; from May to September the intense cold varies little from month to month.

The winter temperatures near the pole have never been observed, but the mean for July must be very low; −80° was

recorded at lat. 80° S. in the winter of 1934. On the Barrier it was estimated at well below —35°; the lowest record was —76° near Ross Island on 6 July 1911, and other low readings were —57° (Shackleton) and —67° on 15 September 1903 on Ross Island. The mean for August was —15° at McMurdo Sound, but very much lower at Framheim, —49° (Fig. 194),

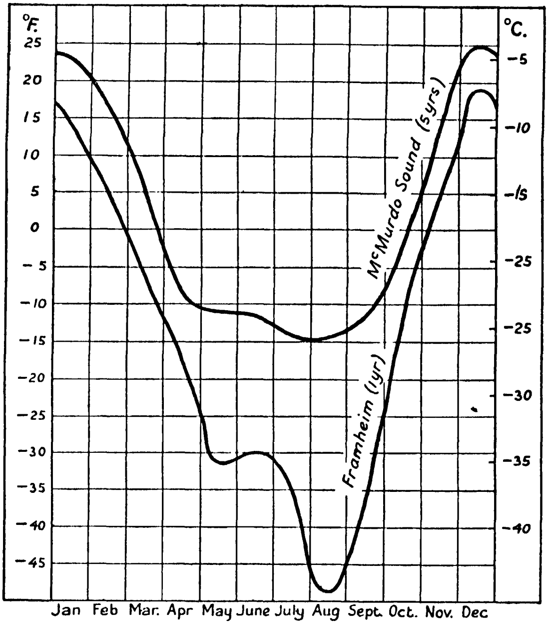


FIG. 194. Mean temperatures.

a difference probably due to the absence of blizzards at Framheim, where the surface layer of very cold air is not often churned up and dissipated, while at McMurdo Sound the frequent blizzards, though one of the greatest trials of life, bring higher temperatures. Winter is naturally much warmer on the ocean coasts, but the means are probably below zero everywhere. The middle of the Ross Sea is warmer than the coasts, for the winter pack-ice is thin and sometimes not continuous.

Very cold winters are to be expected on a great snow-covered plateau lying round the pole itself, much of it without insolation for several months to replace the extremely rapid loss of heat by radiation. Possibly the middle has the coldest winters

of the globe, but no records exist to prove it; the winters are not nearly so cold round the Ross Sea and on the outer coasts as in the interior of Siberia. The table on page 571 shows that the difference in temperature between Antarctica and the ice-covered seas from which islands and ships provide some records is very large in winter, much larger than in summer when it probably does not exceed 20°.

PRECIPITATION

Except for occasional rain on the outer coasts in summer, all the precipitation is snow. Snowfall is always difficult of measurement, the more so in Antarctica where it consists of small dry crystals, at the mercy of the wind which carries it over instead of into the gauges; and in the strong winds with which most of it is associated a great deal of old snow is swept up from the surface and mixed with the new. Estimates of the true snowfall can only be approximate. On the high plateau the cyclonic depressions, which sometimes have influence far inland, are the likely source of most of the precipitation; in addition fine ice-crystals are often observed, some falling perhaps from cirrus clouds, and the deposits of hoar-frost, sometimes thick, make an appreciable contribution.

The annual means are very uncertain. Some useful indications have been got in a few places where measurements of the depth of snow accumulated during a number of years, and the equivalent in rainfall, have been possible. But the considerable allowance due for loss by evaporation, ablation, and in a few localities by run-off of melt-water, can be only rough estimates at best. That precipitation exceeds loss by those processes may be shown by the outflow from the continent in the form of huge tabular icebergs calved off from the ice cliffs, and by the great drift of snow to the sea in strong off-shore winds. But the opinion is held by some that the outflow is drawing not only on the present-day precipitation but also on a much heavier precipitation in the fairly recent past still in process of removal.

Estimates of the mean annual precipitation are:

Ross Sea, Great Barrier . .	7·5	inches of	equivalent rain
Cape Evans	16	,,	snow
Cape Adare	14	,,	equivalent rain
Gauss Station . . .	32	,,	snow
Port Charcot	15	,,	equivalent rain

No figure can be suggested for the polar plateau, but the few explorers consider that some, but very small, accretion of snow occurs. For Antarctica as a whole Meinardus gives the following estimate (in equivalent inches of rain):

	Lat. °S.			
	65, 70	*75, 80*	*85, 90*	*70–90*
Precipitation	18	3·2	0·8	2·8
Loss by evaporation and ablation	8	1·6	0·4	1·2
Resultant	10	1·6	0·4	1·6

Considerably higher estimates for the outer coasts have been suggested.

With regard to the seasonal distribution, the Ross Sea area has most precipitation in late spring and summer; at the *Gauss* station winter gave the greatest increase in depth of snow; at Port Charcot spring and summer had most precipitation. Summer has the favouring factors of higher temperature and humidity of the air and less wind velocity; on the other hand winter is probably more subject (on the outer coasts at any rate) to cyclonic disturbances, and has less evaporation.

Sunshine

Antarctica enjoys very clear skies and long sunshine in the summer months, the sunshine traces being sometimes continuous for the whole 24 hours. In December 1903 the *Discovery* station at McMurdo Sound recorded 490 hours, 66 per cent. of the possible, and in a year 1,725 hours, which is more than in the sunniest parts of England, though the sun was above the horizon for only 246 days. The totals recorded at Cape Evans were:

November 1911	378 hours
December 1911	433 ,,
January 1912	412 ,,
November 1912	335 ,,
December 1912	334 ,,

EQUIVALENTS

TEMPERATURE, °F. AND °C.

Fahr.	*Cent.*	*Fahr.*	*Cent.*	*Fahr.*	*Cent.*	*Fahr.*	*Cent.*	*Fahr.*	*Cent.*
—20·0	−28·9	**+10·0**	−12·2	**+40·0**	+ 4·4	**+70·0**	+21·1	**+100·0**	+37·8
19·5	28·6	10·5	11·9	40·5	4·7	70·5	21·4	100·5	38·1
19·0	28·3	11·0	11·7	41·0	5·0	71·0	21·7	101·0	38·3
18·5	28·1	11·5	11·4	41·5	5·3	71·5	21·9	101·5	38·6
18·0	27·8	12·0	11·1	42·0	5·6	72·0	22·2	102·0	38·9
17·5	27·5	12·5	10·8	42·5	5·8	72·5	22·5	102·5	39·2
17·0	27·2	13·0	10·6	43·0	6·1	73·0	22·8	103·0	39·4
16·5	26·9	13·5	10·3	43·5	6·4	73·5	23·1	103·5	39·7
16·0	26·7	14·0	**10·0**	44·0	6·7	74·0	23·3	104·0	**40·0**
15·5	26·4	14·5	9·7	44·5	6·9	74·5	23·6	104·5	40·3
15·0	26·1	15·0	9·4	45·0	7·2	75·0	23·9	105·0	40·6
14·5	25·8	15·5	9·2	45·5	7·5	75·5	24·2	105·5	40·8
14·0	25·6	16·0	8·9	46·0	7·8	76·0	24·4	106·0	41·1
13·5	25·3	16·5	8·6	46·5	8·1	76·5	24·7	106·5	41·4
13·0	25·0	17·0	8·3	47·0	8·3	77·0	25·0	107·0	41·7
12·5	24·7	17·5	8·1	47·5	8·6	77·5	25·3	107·5	41·9
12·0	24·4	18·0	7·8	48·0	8·9	78·0	25·6	108·0	42·2
11·5	24·2	18·5	7·5	48·5	9·2	78·5	25·8	108·5	42·5
11·0	23·9	19·0	7·2	49·0	9·4	79·0	26·1	109·0	42·8
10·5	23·6	19·5	6·9	49·5	9·7	79·5	26·4	109·5	43·1
10·0	23·3	**20·0**	6·7	**50·0**	**10·0**	**80·0**	26·7	**110·0**	43·3
9·5	23·1	20·5	6·4	50·5	10·3	80·5	26·9	110·5	43·6
9·0	22·8	21·0	6·1	51·0	10·6	81·0	27·2	111·0	43·9
8·5	22·5	21·5	5·8	51·5	10·8	81·5	27·5	111·5	44·2
8·0	22·2	22·0	5·6	52·0	11·1	82·0	27·8	112·0	44·4
7·5	21·9	22·5	5·3	52·5	11·4	82·5	28·1	112·5	44·7
7·0	21·7	23·0	5·0	53·0	11·7	83·0	28·3	113·0	45·0
6·5	21·4	23·5	4·7	53·5	11·9	83·5	28·6	113·5	45·3
6·0	21·1	24·0	4·4	54·0	12·2	84·0	28·9	114·0	45·6
5·5	20·8	24·5	4·2	54·5	12·5	84·5	29·2	114·5	45·8
5·0	20·6	25·0	3·9	55·0	12·8	85·0	29·4	115·0	46·1
4·5	20·3	25·5	3·6	55·5	13·1	85·5	29·7	115·5	46·4
4·0	**20·0**	26·0	3·3	56·0	13·3	86·0	**30·0**	116·0	46·7
3·5	19·7	26·5	3·1	56·5	13·6	86·5	30·3	116·5	46·9
3·0	19·4	27·0	2·8	57·0	13·9	87·0	30·6	117·0	47·2
2·5	19·2	27·5	2·5	57·5	14·2	87·5	30·8	117·5	47·5
2·0	18·9	28·0	2·2	58·0	14·4	88·0	31·1	118·0	47·8
1·5	18·6	28·5	1·9	58·5	14·7	88·5	31·4	118·5	48·1
1·0	18·3	29·0	1·7	59·0	15·0	89·0	31·7	119·0	48·3
0·5	18·1	29·5	1·4	59·5	15·3	89·5	31·9	119·5	48·6
0·0	17·8	**30·0**	1·1	**60·0**	15·6	**90·0**	32·2	**120·0**	48·9
0·5	17·5	30·5	0·8	60·5	15·8	90·5	32·5	120·5	49·2
1·0	17·2	31·0	0·6	61·0	16·1	91·0	32·8	121·0	49·4
1·5	16·9	31·5	− 0·3	61·5	16·4	91·5	33·1	121·5	49·7
2·0	16·7	32·0	0·0	62·0	16·7	92·0	33·3	122·0	**50·0**
2·5	16·4	32·5	+ 0·3	62·5	16·9	92·5	33·6	122·5	50·3
3·0	16·1	33·0	0·6	63·0	17·2	93·0	33·9	123·0	50·6
3·5	15·8	33·5	0·8	63·5	17·5	93·5	34·2	123·5	50·8
4·0	15·6	34·0	1·1	64·0	17·8	94·0	34·4	124·0	51·1
4·5	15·3	34·5	1·4	64·5	18·1	94·5	34·7	124·5	51·4
5·0	15·0	35·0	1·7	65·0	18·3	95·0	35·0	125·0	51·7
5·5	14·7	35·5	1·9	65·5	18·6	95·5	35·3	125·5	51·9
6·0	14·4	36·0	2·2	66·0	18·9	96·0	35·6	126·0	52·2
6·5	14·2	36·5	2·5	66·5	19·2	96·5	35·8	126·5	52·5
7·0	13·9	37·0	2·8	67·0	19·4	97·0	36·1	127·0	52·8
7·5	13·6	37·5	3·1	67·5	19·7	97·5	36·4	127·5	53·1
8·0	13·3	38·0	3·3	68·0	**20·0**	98·0	36·7	128·0	53·3
8·5	13·1	38·5	3·6	68·5	20·3	98·5	36·9	128·5	53·6
9·0	12·8	39·0	3·9	69·0	20·6	99·0	37·2	129·0	53·9
9·5	12·5	39·5	4·2	69·5	20·8	99·5	37·5	129·5	54·2

INCHES AND MILLIMETRES

Inches	*Milli-metres*	*Inches*	*Milli-metres*	*Inches*	*Milli-metres*	*Inches*	*Milli-metres*	*Inches*	*Milli-metres*
0·05	1·3	3·3	83·8	6·6	167·6	9·9	251·5	30·3	769·6
0·1	2·5	3·4	86·4	6·7	170·2	**10·0**	254·0	30·4	772·2
0·2	5·1	3·5	88·9	6·8	172·7	11·0	279·4	30·5	774·7
0·3	7·6	3·6	91·4	6·9	175·3	12·0	304·8	31·0	787·4
0·4	10·2	3·7	94·0	**7·0**	177·8	13·0	330·2	32·0	812·8
0·5	12·7	3·8	96·5	7·1	180·3	14·0	355·6	33·0	838·2
0·6	15·2	3·9	99·1	7·2	182·9	15·0	381·0	34·0	863·6
0·7	17·8	**4·0**	101·6	7·3	185·4	16·0	406·4	35·0	889·0
0·8	20·3	4·1	104·1	7·4	188·0	17·0	431·8	36·0	914·4
0·9	22·9	4·2	106·7	7·5	190·5	18·0	457·2	37·0	939·8
1·0	25·4	4·3	109·2	7·6	193·0	19·0	482·6	38·0	965·2
1·1	27·9	4·4	111·8	7·7	195·6	**20·0**	508·0	39·0	990·6
1·2	30·5	4·5	114·3	7·8	198·1	21·0	533·4	**40·0**	1016·0
1·3	33·0	4·6	116·8	7·9	200·7	22·0	558·8	41·0	1041·4
1·4	35·6	4·7	119·4	**8·0**	203·2	23·0	584·2	42·0	1066·8
1·5	38·1	4·8	121·9	8·1	205·7	24·0	609·6	43·0	1092·2
1·6	40·6	4·9	124·5	8·2	208·3	25·0	635·0	44·0	1117·6
1·7	43·2	**5·0**	127·0	8·3	210·8	26·0	660·4	45·0	1143·0
1·8	45·7	5·1	129·5	8·4	213·4	27·0	685·8	46·0	1168·4
1·9	48·3	5·2	132·1	8·5	215·9	28·0	711·2	47·0	1193·8
2·0	50·8	5·3	134·6	8·6	218·4	29·0	736·6	48·0	1219·2
2·1	53·3	5·4	137·2	8·7	221·0	29·1	739·1	49·0	1244·6
2·2	55·9	5·5	139·7	8·8	223·5	29·2	741·7	**50·0**	1270·0
2·3	58·4	5·6	142·2	8·9	226·1	29·3	744·2	51·0	1295·4
2·4	61·0	5·7	144·8	**9·0**	228·6	29·4	746·8	52·0	1320·8
2·5	63·5	5·8	147·3	9·1	231·1	29·5	749·3	53·0	1346·2
2·6	66·0	5·9	149·9	9·2	233·7	29·6	751·8	54·0	1371·6
2·7	68·6	**6·0**	152·4	9·3	236·2	29·7	754·4	55·0	1397·0
2·8	71·1	6·1	154·9	9·4	238·8	29·8	756·9	56·0	1422·4
2·9	73·7	6·2	157·5	9·5	241·3	29·9	759·5	57·0	1447·8
3·0	76·2	6·3	160·0	9·6	243·8	**30·0**	762·0	58·0	1473·2
3·1	78·7	6·4	162·6	9·7	246·4	30·1	764·5	59·0	1498·6
3·2	81·3	6·5	165·1	9·8	248·9	30·2	767·1	**60·0**	1524·0

PRESSURE

INCHES AND MILLIBARS

Equivalents in Millibars of Inches of Mercury at 32° F., Latitude 45°

Mercury Inches	*0·00*	*0·05*
	Millibars	
28·0	948·2	949·9
28·1	951·6	953·2
28·2	954·9	956·6
28·3	958·3	960·0
28·4	961·7	963·4
28·5	965·1	966·8
28·6	968·5	970·2
28·7	971·9	973·6
28·8	975·3	977·0
28·9	978·6	980·3
29·0	982·0	983·7
29·1	985·4	987·1
29·2	988·8	990·5
29·3	992·2	993·9
29·4	995·6	997·3
29·5	999·0	1000·7
29·6	1002·4	1004·0
29·7	1005·7	1007·4
29·8	1009·1	1010·8
29·9	1012·5	1014·2
30·0	1015·9	1017·6
30·1	1019·3	1021·0
30·2	1022·7	1024·4
30·3	1026·1	1027·7
30·4	1029·4	1031·1
30·5	1032·8	1034·5
30·6	1036·2	1037·9
30·7	1039·6	1041·3
30·8	1043·0	1044·7
30·9	1046·4	1048·1

A SHORT BIBLIOGRAPHY

GENERAL WORKS

BUCHAN, A. 'Reports on Atmospheric Circulation', *Challenger Reports.* Edinburgh, 1889.

Deutsche Seewarte. *Indischer Ozean.* Hamburg, 1891.

—— *Stiller Ozean.* Hamburg, 1896.

—— *Atlantischer Ozean.* Hamburg, 1902.

BARTHOLOMEW, J. *Atlas of Meteorology.* Westminster, 1899.

HANN, J. *Handbuch der Klimatologie.* Stuttgart, 1908 (and many papers in *Met. Zeit.*).

Oxford Survey of the British Empire (chapters on climates by many authors). Oxford, 1914.

NEWNHAM, Mrs. E. V. 'Hurricanes and Tropical Revolving Storms.' *Geophysical Memoir* 19. London, 1922.

DE LA BLACHE, V. and GALLOIS, L. (editors). *Géographie universelle* (chapters on climates). Paris, 1927–.

World Weather Records. Smithsonian Institution. Washington, 1929–.

KÖPPEN, W., u. GEIGER, R. *Handbuch der Klimatologie.* Berlin, 1930–. (Contains comprehensive bibliographies.)

KÖPPEN, W. *Grundriss der Klimakunde.* Berlin, 1931.

SHAW, Sir N., with the assistance of E. AUSTIN. *Manual of Meteorology,* vol. ii. Cambridge, 1936.

BROOKS, C. E. P. 'Distribution of Thunderstorms over the Globe.' *Geophysical Memoir,* 3, 24; 1925.

—— *Climate.* London, 1932.

—— Many papers in *Quart. Journ. Roy. Met. Soc.*, London, and other journals.

Atlas of Climatic Charts of the Oceans. U.S. Weather Bureau. Washington, 1938.

GRENFELL PRICE, A. *White Settlers in the Tropics.* New York, 1939.

Climate and Man. U.S. Department of Agriculture. Washington, 1941.

HAURWITZ, B., and AUSTIN, J. M. *Climatology.* New York, 1944.

DE MARTONNE, E. *Traité de géographie physique,* i. Paris, 1947.

GARBELL, M. A. *Tropical and Equatorial Meteorology.* London, 1947.

KENDREW, W. G. *Climatology.* Oxford, 1949.

MILLER, A. *Climatology.* London, 1949.

GEIGER, R. *The Climate near the Ground.* Harvard University Press, 1950.

BROOKS, C. E. P., and others. 'Upper Winds over the World.' *Geophysical Memoir* 85; London, 1950.

Meteorologische Zeitschrift (to end of publication).

Quarterly Journal of the Royal Meteorological Society, London.

Annalen der Hyd. u. Marit. Meteorologie. Deutsche Seewarte.

Gerlands Beiträge zur Geophysik. Leipzig.
Monthly Weather Review. Weather Bureau, Washington.
Bulletin of the American Meteorological Society.

AFRICA

BROOKS, C. E. P., and MIRLEES, S. T. A. 'A Study of the Atmospheric Circulation over Tropical Africa.' *Geoph. Mem.* 55. London, 1932.
GRANDIDIER, G. *Atlas des colonies françaises.* Paris, 1934.

SCHIRMER, H. *Le Sahara.* Paris, 1893.
LASSERRE, A. 'Aperçu météorologique' in *Les Territoires du sud de l'Algérie*, i. Alger, 1930.
BROOKS, C. E. P. 'Le Climat du Sahara et de l'Arabie', in Hachisuka, *Le Sahara.* Paris, 1932.
PERRET, R. 'Le Climat du Sahara.' *Ann. de géogr.*, 1935.

CHANNEY. *The Climatology of the Gold Coast.* Accra, Dept. of Agriculture.
BROOKS, C. E. P. 'Notes on the Climatology of the British Empire—Sierra Leone.' *Quart. Journ. Roy. Met. Soc.* London, 1922.
—— 'The Rainfall of Nigeria and the Gold Coast.' *Quart. Journ. Roy. Met. Soc.* London, 1916.
AINSLIE, J. R. *Physiography of Southern Nigeria.* Oxford, 1926.
HUBERT, H. *Nouvelles études sur la météorologie de l'Afrique occidentale française.* Paris, 1926.
HAMILTON, R. A., and ARCHIBOLD, J. W. 'Meteorology of Nigeria.' *Quart. Journ. Roy. Met. Soc.* London, 1945.

SUTTON, L. J. *The Climate of Helwan.* Cairo, 1926.
—— *The Climate of Khartoum.* Cairo, 1923.
HAMED, M. *The Climate of Alexandria.* Cairo, 1925.
Atlas of Egypt. Survey Dept., Cairo, 1928.
HURST, H. E., and PHILLIPS, P. *The Nile Basin.* Cairo, 1931.
Climatological Normals for Egypt and the Sudan, Candia, Cyprus, and Abyssinia. Physical Dept., Cairo, 1938.

GILLMAN, C. *A Reconnaissance Survey of the Hydrology of Tanganyika Territory.* Dar-es-Salaam, 1944.
Tables of Means and Extremes, and Annual Summaries. East African Meteorological Department.
KENDREW, W. G. *Meteorological Report on British East Africa.*

GOEDERT. *Le Régime pluvial au Congo Belge.* Brussels, 1938.
BERNARD, E. *Le Climat écologique de la Cuvette Centrale Congolaise.* Brussels, 1945.

RAVET, J. *Atlas climatologique de Madagascar.* Tananarive, 1948.

Yearbook of the Union of South Africa, chapter on Climate. Pretoria.
Union of South Africa, Rainfall normals up to the end of 1925. Irrigation Department, Pretoria.

ASIA

Blanford, H. F. *The Climates and Weather of India, Ceylon, and Burma*. London, 1889.
Eliot, J. *Climatological Atlas of India*. Edinburgh, 1906.
Imperial Gazetteer of India, vol. i, chap. III. *Meteorology*. Oxford, 1909.
Simpson, Sir G. C. 'The South-West Monsoon.' *Quart. Journ. Roy. Met. Soc.*, 1921.
Indian Meteorological Department, Memoirs, Notes.
—— *Climatological Charts of the Indian Monsoon Area*. Poona, 1945.

Gauthier, H. *La Température en Chine*. Shanghai, 1918.
Gherzi, E. *Étude sur la pluie en Chine*. Shanghai, 1928.
—— *Climatic Atlas of East Asia*. Shanghai, 1944.
Kendrew, W. G. 'Climate', in *China*, Buxton, L. D. H. Oxford, 1929.
Chu Cochin. *Climatic Provinces of China*. Nanking, 1930.
Cressey, G. B. *China's Geographic Foundations*. New York, 1934.

Okada, T. *The Climate of Japan*. Tokyo, 1931.
Climatographic Atlas of Japan. Tokyo, 1948.

Braak, C. *The Climate of the Netherlands Indies*. Batavia, 1921–9.
Coronas, J. *The Climate and Weather of the Philippines*. Manila, 1920.
Atlas of the East Indian Seas.
Froc, L. *Atlas of the Tracks of 620 Typhoons, 1893–1918*. Zi-ka-wei, 1920.
Wallace, A. R. *The Malay Archipelago*. London, 1869.

Huntington, Ellsworth. *The Pulse of Asia*. London, 1907.

Climate and Weather of Iraq. Baghdad, 1919.
Climatological Atlas for Iraq. Baghdad, 1945.

Klima der Union der Sozial. Sowjet-Republiken (with Atlases). Leningrad, 1926.
Great Soviet World Atlas. Moscow, 1938.

EUROPE

Hellmann, G. *Untersuchungen über die jährliche Periode der Niederschläge in Europa*. Preussische Akad. der Wissensch., 1924.
Glasspoole, J. 'The Distribution of Average Seasonal Rainfall over Europe.' *Quart. Journ. Roy. Met. Soc.* London, 1929.
Bilham, E. G. *The Climate of the British Isles*. London, 1938.
Abercromby, R., and Goldie, A. H. R. *Weather*. London, 1934.

Rainfall Atlas of the British Isles. Royal Meteorological Society, London, 1926.

Climatological Atlas of the British Isles. Meteorological Office, London, 1952.

GRAARUD, A., and IRGENS, K. *Atlas de climat de Norvège.* Oslo, 1922.

The Book of Normals of Meteorological Elements for the British Isles. Meteorological Office, London.

ANGOT, A. 'Études sur le climat de la France.' *Ann. du Bur. central météor.* 1897, 1900, 1902, 1903.

—— 'Régime des pluies de l'Europe occidentale.' *Ann. du Bur. central météor.* Paris, 1895.

Klimaatlas von Deutschland. Kön. Preussisch. Met. Inst., Berlin, 1921.

WALLÉN, A. *Climate of Sweden.* Stockholm, 1930.

Klimatographie von Oesterreich. Zentralanstalt für Meteor. u. Geodyn., Wien, 1919.

Atlas Climatologic. Inst. Meteor. central. București, 1940.

MAURER, BILLWILLER, u. HESS. *Das Klima der Schweiz.* Frauenfeld, 1909.

FISCHER, T. 'Studien über das Klima der Mittelmeerländer.' *Petermann's Mitteilungen*, Ergänzungsheft No. 58. Gotha, 1879.

Monthly Meteorological Charts of the Mediterranean Sea. H.M.S.O., London, 1919.

PHILIPPSON, A. *Das Mittelmeergebiet.* Leipzig, 1922.

MARIOLOPOULOS, E. G. *Étude sur le climat de la Grèce.* Paris, 1925.

—— et LIVATHENOS, A. N. *Atlas climatique de la Grèce.* Athens, 1935.

ANGOT, A. 'Régime des pluies de la Péninsule Ibérique.' *Ann. du Bur. central météor.* Paris, 1893.

EREDIA, F. 'Il Temperatura in Italia.' *Ann. Uff. centr. meteor.* Rome, 1909.

—— *Le Precipitazioni atmospheriche in Italia, 1880–1905.* Rome, 1908.

Atlante Fisico Economico d'Italia. Milano, 1940.

NORTH AMERICA

KOEPPE, C. E. *The Canadian Climate.* Bloomington, Ill., 1931.

CONNOR, A. J. 'The Climate of Canada', in *Canada Year Book*, 1949.

—— 'The Temperature and Precipitation of North Canada.' *Canada Year Book*, 1930.

—— *The Climate of Manitoba.* Winnipeg, 1939.

Meteorology of the Canadian Arctic. Canada, Dept. of Transport, 1944.

STEFANSSON, V. *Arctic Manual.* New York, 1944.

BOUGHNER, C. C., and THOMAS, M. K. *Climatic Summaries for Selected Stations in the Dominion of Canada.* Toronto, 1948.

WARD, R. DEC. *The Climates of the United States.* New York, 1925.

Climatological Maps of N. America. Brooks, C. F., Connor, A. J., and others. Harvard University Press, 1936.

Summary of the Climatological Data for the United States. U.S. Weather Bureau, 1936.

Bulletins (several) on the Climates of the United States. U.S. Weather Bureau.

Atlas of American Agriculture. U.S. Dept. of Agriculture, 1928.

Monthly ice charts, Western North Atlantic. Meteorological Office, London, 1944.

SOUTH AND CENTRAL AMERICA. THE WEST INDIES

SERRA. *La Circulation générale de l'Amérique du Sud.* 1939.

MOSSMAN, R. C. 'The Climate of Chile.' *Journ. of the Scot. Met. Soc.*, 1911.

JEFFERSON, M. 'The Rainfall of Chile.' *American Geogr. Soc. Research Series*, No. 7.

ESTRADA, R. P. *Climas de Bolivia.* La Paz, 1946.

RÖHL, E. *Climatología de Venezuela.* 1946.

CARVALHO, C. DE. *Météorologie du Brésil.* London, 1917.

MORIZE, H. *Contribuïção ao Estudo do Clima do Brasil.* Rio de Janeiro, 1922.

BATES, H. W. *The Naturalist on the River Amazons.* London, 1863.

WALLACE, A. R. *A Narrative of Travels on the Amazon and the Rio Negro.* London, 1853.

DAVIS, W. G. *Climate of the Argentine Republic.* Buenos Aires, 1910.

Estadísticas climatológicas, 1928–37, República Argentina. Buenos Aires, 1944.

El Regimen Pluviométrico de la República Argentina. Buenos Aires, 1943.

VIVO-GOMEZ. *Climatología de Mexico.* Mexico, 1943.

TACUBAYA. *Atlas Climatológico de Mexico.* Serv. Met. Mexicano, 1939.

REED, W. W. 'Climatological Data for Central America.' *Monthly Weather Review*, 51, 1923.

HALL, M. *The Rainfall of Jamaica.* Kingston, 1923.

CLINE, I. M. *Tropical Cyclones.* New York, 1926.

AUSTRALIA AND NEW ZEALAND

HUNT, QUAYLE, and TAYLOR. *The Climate and Weather of Australia.* Melbourne, 1913.

TAYLOR, G. *Australian Meteorology.* Oxford, 1920.

GENTILLI, J. *Australian Climates and Resources.* Melbourne, 1947.

Year Book of the Commonwealth of Australia. Chapter on Climate. Melbourne, annual.

Climatological Atlas of Australia. Bureau of Meteorology, Melbourne, 1941.
Bulletins (several). Bureau of Meteorology, Melbourne.

The New Zealand Year Book. Chapter on Climate. Wellington, annual.
SEELYE. *Maps of average Rainfall in New Zealand.* Wellington, 1945.

ANTARCTICA

National Antarctic Expedition, 1901–4; *Meteorology.* London, 1908.
SIMPSON, Sir G. C. *British Antarctic Expedition: Meteorology.* Calcutta, 1919.

NOTE

Most of the latest reliable information is to be found in the numerous publications prepared by the Meteorological Offices of many countries, primarily for use by the Services on sea and land and in the air; many have been issued for general use. The regular annual volumes of current observations are also available.

The meteorological journals named under General Works above, and many other journals, contain useful papers on climatography, most of them dealing with the climates of small areas.

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